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ADDENDA ET CORRIGENDA.

Page 62, line 19, *for* "a round" *read* "around."
„ 62, line 3 from bottom, *for* "other" *read* "older."
„ 64, line 9 from bottom, *for* "plain" *read* "plane."
„ 125, line 17, *for* "magna" *read* "magma."
„ 178, To the heading, "CAVERNS" *add* "AND UNDERGROUND WATER."
„ 275, Fig 2 is inverted.
„ 466, Fig. 2, The bed "2" on the west side of the fault should be about half mile farther south. The positions of the beds are correctly stated in the text.

INSTRUCTIONS FOR BINDING AND DATES OF PUBLICATION.

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PROCEEDINGS

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VOL. XVI.

NOTES ON THE TEETH OF SHARKS AND SKATES FROM ENGLISH EOCENE FORMATIONS.

By A. SMITH WOODWARD, F.L.S., F.G.S., of the British Museum (Natural History).

(*Read June 3rd*, 1898.)

[PLATE I.]

THE sharks and skates of the Eocene period are very imperfectly known. They are represented by a few nearly complete skeletons in the fissile limestone of Monte Bolca* and Monte Postale† in Northern Italy, and by the nearly complete skeleton of one genus‡ in the marly Green River Formation of Wyoming, U.S.A. In other localities they are known merely by portions of dentition, detached teeth, cartilage, and vertebræ. Nevertheless, it is evident that the genera and species indicated by these fragments are closely similar to those surviving in existing seas. The fossils can therefore be directly compared with the corresponding hard structures of the genera of the present day; and if the parts were in all cases distinctive, it would be an easy task to restore the Eocene Selachian fauna from the abundant materials now collected in museums. Unfortunately, however, as already emphasised on a former occasion,§ the detached teeth of sharks and skates are not always distinctive; and the generic and specific determination of them is little more than guesswork, while that of the associated vertebræ is, if possible, even more unsatisfactory.

* O. Jaekel, "Die eocänen Selachier vom Monte Bolca" (Berlin, 1894).

† Kner and Steindachner, "Neue Beiträge zur Kenntniss der fossilen Fische Oesterreichs," *Denkschr. k. Akad. Wiss., math.-naturw. Cl.*, vol. xxi (1863), p. 32, Pl. VI, Fig. 2

‡ *Xiphotrygon*, E. D. Cope, "Vertebrata of the Tertiary Formations of the West," Book I (*Rep. U.S. Geol. Surv. Territ*, vol. iii, 1884), p. 50, Pl. I, Figs. 1, 5.

§ A. S. Woodward, "Notes on the Sharks' Teeth from British Cretaceous Formations," *Proc. Geol. Assoc.*, vol. xiii (1894), p. 190.

In presenting these notes on the Selachian teeth from British Eocene Formations, it must therefore be understood that the proposed nomenclature and arrangement of the fossils under consideration are in most cases quite tentative and liable to change when the fishes or even the jaws to which they belong are discovered in their entirety. In some instances the writer has already found reason to modify the determinations suggested in Part I of the "Catalogue of Fossil Fishes in the British Museum," published in 1889. The members of the Geologists' Association are in an especially favourable position for the further elucidation of the subject; and it is hoped that the following brief outline of our present knowledge and speculations will lead to new advances. These notes merely record the species which it seems possible to recognise. Students desiring detailed references to the literature and synonymy may consult the Catalogue just mentioned.

SUB-ORDER TECTOSPONDYLI.

FAMILY *SPINACIDÆ*.

GENUS Acanthias.

Though ranging from the Cretaceous upwards, the spiny dog-fishes are only known from the English Eocene by a few small teeth discovered by Mr. Sydney C. Cockerell in the Woolwich and Reading Beds of Chislehurst. These teeth closely resemble those of the existing *Acanthias*, and have been referred to this genus by Jaekel.* Two of them are shown of the natural size in Pl. I, Figs. 1, 2. They have a very broad and low, laterally-compressed crown, with the anterior margin arched and the posterior margin deeply notched; and there are sometimes faint traces of serrations on the sharp edge. Identical teeth have been described from the Heersian Beds of Belgium under the name of *Notidanus orpiensis*,† and the species is wrongly referred to *Carcharias (Scoliodon)* in the British Museum Catalogue (*tom. cit.*, p. 436).

FAMILY *SQUATINIDÆ*.

GENUS Squatina.

Two characteristic teeth of the "angel-fish," *Squatina*, were discovered by Mr. N. T. Wetherell in the London Clay of Highgate Archway, and a third example by Mr. Cockerell in the Woolwich and Reading Beds of Chislehurst. They are shown, of the natural size, in Pl. I, Figs. 3–5, but are insufficient for specific determination.

* O. Jaekel, *op. cit.*, p. 156.
† C. Winkler, *Archiv. Mus. Teyler*, vol. iv (1876), p. 12, Pl. I, Figs. 13—17.

FAMILY *PRISTIDÆ*.

GENUS Pristis.

Portions of the remarkable toothed snout of the "saw-fish," *Pristis*, have long been known from the Bracklesham Beds of the Sussex coast; and detached rostral teeth of *Pristis bisulcata*, as the species is termed,* are not uncommon fossils in that formation. These teeth are laterally-compressed pegs, grooved along the posterior border, exactly similar to those of most living species. Indeed, it is clear that the unique rostrum of *Pristis* was already fully developed in the Eocene period. Similar rostral teeth occur in the Barton Clay of Hampshire, one having been named *P. hastingsiæ* by Agassiz (*tom. cit.*, p. 382*); and there is a curiously bent form, *P. contorta*,† also in the Bracklesham Beds. The genus is not yet known from the Lower Eocene.

FAMILY *MYLIOBATIDÆ*.

GENUS Myliobatis.

The great "eagle-rays" with a compact pavement of flattened crushing teeth in each jaw must have been very abundant in Eocene seas. Fragments of their dentition are common in the London Clay, the Bracklesham Beds, and the Barton Clay; and all three surviving genera seem to occur. Of these, *Myliobatis* is by far the commonest, and evidently represented by several species, which are not readily distinguished. The dentition of each jaw in this genus comprises large, flattened, hexagonal teeth, arranged in seven antero-posterior series. In very young individuals, the teeth are all approximately of equal size, but quite early in life the median teeth begin to become relatively very broad, and as the animal grows, this disproportion of the median teeth gradually becomes greater and greater. When unworn or unabraded, the grinding surface of the teeth is covered with a thin enamel-like layer of gano-dentine, usually marked with antero-posteriorly directed striations; but when this layer is removed, the tooth has a punctate appearance, owing to the exposure of the vertical nutritive canals traversing the underlying vascular dentine. In naming the fossils, it is thus necessary to take into account the size of the specimen, and remember that the surface markings depend upon the state of preservation. It is also necessary to note that the dental plate of the lower jaw is flat, while that of the upper jaw curves round the supporting

* L. Agassiz, "Rech. Poiss. Foss.," vol. iii (1843), p. 382*, Pl. XLI.
† F. Dixon, "Geology and Fossils of Sussex" (1850), p. 202, Pl. XII, Figs. 9, 10.

cartilage. No less than fifteen names have been given to English Eocene specimens, but a study of the very large collection in the British Museum, with the considerations just mentioned in view, suggests that only five species are represented.

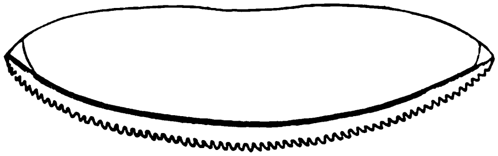


FIG. 1.—TRANSVERSE SECTION OF LOWER DENTITION OF *Myliobatis dixoni*, AGASSIZ.

1. *Myliobatis dixoni*, Agassiz. This seems to be the commonest species in the Bracklesham Beds and Barton Clay, but it has not yet been definitely recognised in the London Clay. The teeth are very massive and conspicuously striated when unabraded; in transverse section (Fig. 1) the surface of the crown is shown to be arched from side to side. The lateral teeth are much longer than broad, and even in the largest specimens the median teeth are rarely more than five times as broad as long.

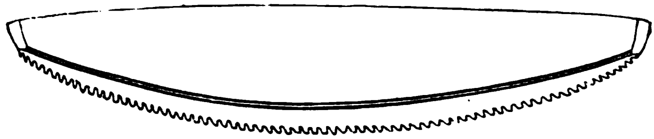


FIG. 2.—TRANSVERSE SECTION OF LOWER DENTITION OF *Myliobatis striatus*, BUCKLAND.

2. *Myliobatis striatus*, Buckland. This is another large species confined to the Bracklesham Beds and Barton Clay, with the dental crown very little arched from side to side (Fig. 2). The median teeth in the larger specimens are at least six times as broad as long, and the lateral teeth always longer than broad.

3. *Myliobatis goniopleurus*, Agassiz. A rarer species apparently occurring both in the London Clay and the Bracklesham Beds, though the only known specimen labelled "Isle of Sheppey" is the type. The teeth are of similar proportions to those of *M. striatus*, but thicker and considerably raised in the middle.

4. *Myliobatis toliapicus*, Agassiz. A common species in the London Clay, Bracklesham Beds, and Barton Clay. The dentition is comparatively thin, and the contour of the crown is flat in the lower jaw, nearly so in the upper jaw. The median teeth in the adult are at least six times as broad as long, while the lateral teeth are as broad as long, more or less diamond-shaped.

When preserved the grinding surface is seen to be remarkably smooth.

5. *Myliobatis latidens*, A. S. Woodward. This is a very small species from the Bracklesham Beds, the largest known dentition measuring only about three centimetres across. The lower dentition is flattened, and the upper median teeth are only slightly arched from side to side. The median teeth in the adult are not less than eight times as broad as long, while the lateral teeth are always at least as broad as long.

The characteristic serrated tail-spines of the Myliobatidæ also occur in the English Eocene, and five have received names (*Myliobatis acutus*, Ag., *M. canaliculatus*, Ag., *M. lateralis*, Ag., *M. marginalis*, Ag., and *M. oweni*, Ag.); but they cannot be either generically or specifically determined, and some of these fossils may belong to Trygonidæ.

It is interesting to add that a complete fish with the dentition of *Myliobatis* is known from the Upper Eocene of Monte Bolca in Northern Italy.* This is supposed to differ from the recent *Myliobatis* in the continuous extension of the pectoral fins forward to the front of the head, and is thus placed in a distinct genus, *Promyliobatis*.† The English Eocene teeth may have belonged to a similar fish, but no distinctive features can be observed in the dentition.

GENUS **Rhinoptera** OR **Zygobatis**.

Rhinoptera has the teeth in five or more antero-posterior series, the middle being the largest, the first—or first and second—lateral series on each side somewhat smaller, and the others approximately as broad as long. The dentition is bent round the cartilage of each jaw. The only known evidence of this genus in the Eocene is a unique jaw in the British Museum from the London Clay of Sheppey.‡ The teeth in this specimen are transversely channelled on the crown, and arranged in nine antero-posterior series.

GENUS **Aetobatis**.

As in *Myliobatis* the dentition in this genus is bent round the supporting cartilage of the upper jaw and forms a flat plate in the lower jaw; but there is only one very broad series of teeth. The upper teeth are much like those of *Myliobatis*, only differing in their truncated lateral ends; but the lower teeth are more or less strongly curved or V-shaped. Such teeth occur in all the English Eocene deposits, but mostly detached and not specifically determinable. Six names have been proposed for

* A. de Zigno, *Mem. R. Istit. Veneto*, vol. xxii (1887), p. 681, Pl. V, Fig. 1.
† O. Jaekel, *op. cit.*, p. 152.
‡ *Rhinoptera daviesi*, A. S. Woodward, "Catal. Foss. Fishes B. M.," Pt. 1 (1889), p. 126, Pl. III, Fig. 6.

them, but at present it is only possible to distinguish two forms, a flattened, low-crowned tooth (*A. irregularis*, Agassiz), and a thickened tooth raised in the middle (*A. marginalis*, Agassiz).

SUB-ORDER ASTEROSPONDYLI.

FAMILY *NOTIDANIDÆ.*

GENUS **Notidanus.**

The saw-like teeth of *Notidanus* are not uncommon in the London Clay, but they seem to be unknown in the Bracklesham Beds, and they are rare in the Barton Clay. All the known teeth from the London Clay appear to belong to one small species, *Notidanus serratissimus*, Agassiz, and they exhibit the usual variations. Some, which probably belong to the upper jaw (Pl. I, Fig. 6), have a large principal cusp, with strong serrations in front, and four or five diminishing cusps behind. Other teeth (Pl. I, Fig. 7), which are referable to the side of the lower jaw, exhibit as many as seven or eight cusps behind the principal cusp. The Barton Clay teeth are larger than these, and are probably to be identified with *Notidanus primigenius*, Agassiz, which is common in the Lower Miocene of the Continent, and also occurs in the Upper Eocene of North Germany.

The upper front teeth of the existing *Notidanus* are simple awl-shaped cusps, and it seems not unlikely that the so-called *Xiphodolamia ensis*, described by Leidy* from the "marls of New Jersey," is founded on some of these. Three teeth obtained from the London Clay of Sheppey by the late Mr. Wetherell are apparently of the same nature, only differing from the usual form in the crown (Pl. I, Figs. 8, 8*a*) exhibiting one cutting edge and a rounded border instead of two cutting edges. The crown is fixed obliquely on a small, nearly square base (Pl. I, Fig. 8*b*), which is imperfectly divided into two roots. A broken crown in the Wetherell collection proves that it is solid, and does not resemble that of the Carchariidæ in structure—an important observation, because a tooth of nearly similar outward form from the Tertiary of New Zealand is determined by Jaekel,† on histological evidence, to belong to *Hemigaleus*, a genus of Carchariidæ.

FAMILY *CESTRACIONTIDÆ.*

GENUS **Cestracion.**

The Port Jackson shark is already known to have survived in the northern hemisphere until the Middle Eocene period, by

* J. Leidy, *Journ. Acad. Nat. Sci. Philad.* [2], vol. viii (1877), p. 252, Pl. XXXIV, Figs. 25—30.

† O. Jaekel, *op. cit.*, p. 167, Fig. 30.

the discovery of teeth in the Bruxellian Formation of Belgium.* In England, however, the writer has only identified two Cestraciont teeth from the Eocene, and both these from the base of the series. The first specimen (Pl. I, Fig. 9) was discovered by Mr. Wetherell in the London Clay at Highgate Archway. It is a lateral tooth, characterised by a prominent longitudinal crest and obtusely angulated extremities; it is rather larger than the Bruxellian form, and must remain for the present without specific determination. The second specimen, also in the British Museum (No. P. 4104*b*), is a still larger tooth incomplete at one end, obtained by Mr. Sydney C. Cockerell in the Lower Eocene of Chislehurst. Its rugose crown is gently rounded, not ridged or keeled.

FAMILY *LAMNIDÆ*.

The teeth of this comparatively modern family are all solid when completely formed, and those of the principal genera are relatively large, more or less compressed, lanceolate, and pointed, adapted for lacerating, At least four, perhaps five, genera are represented in the Eocene; and, so far as can be judged from teeth and vertebræ, the four still survive in existing seas.

GENUS **Odontaspis.**

In this genus all except a few hindermost teeth exhibit a high, narrow, compressed crown, flanked by one or two pairs of small pointed denticles. The anterior teeth are especially high-crowned, comparatively large and slender, with a much-produced bifurcated root. At least four species are known from the English Eocene.

1. *Odontaspis rutoti*, Winkler sp. (Pl. I, Figs. 10, 11). The teeth thus named denote a comparatively small species, known only from the base of the Eocene. In England they have been found by Mr. Sydney C. Cockerell in the Thanet Sands at the Reculvers, Kent. The dental crown is robust, with smooth, inner face, and the outer base-line not straight but excavated by a slight re-entering angle. Two pairs of pointed lateral denticles are usually present, the outer being insignificant. These teeth are known from the Heersian, Landenian, and Ypresian beds of Belgium, and are of special interest as being almost identical with the teeth named *Odontaspis bronni* from the uppermost Cretaceous of Holland and Belgium.

2. *Odontaspis cuspidata*, Agassiz sp. (Pl. I, Figs. 12—14). The teeth of this form, which occur throughout the English Eocene deposits from the Thanet Sands upwards, were originally named *Lamna* (*Odontaspis*) *hopei* by Agassiz; but a study of the large

* *Cestracion duponti*, T. C. Winkler, *Archiv. Mus. Teyler*, vol. iv (1876), p. 17, Pl. II, Figs. 1—3; A. S. Woodward, *Geol. Mag.* [3], vol. viii (1891), p. 105, Pl. III, Fig. 1.

collection in the British Museum shows that they cannot be distinguished from those of the Continental Lower Miocene previously described by Agassiz as *Lamna cuspidata*. The anterior teeth, though much elevated and narrow, are moderately stout; the long crown is only slightly curved, and its convex inner face is quite smooth. There is a single pair of very small lateral denticles—sometimes mere rudimentary prickles; and the nutritive foramen on the prominent inner side of the root is placed in a deep cleft (Fig. 13). The lateral teeth (Fig. 14) differ from these precisely as they do in the existing *Odontaspis*, and there need be little hesitation in referring the species to the latter genus. A few interesting new facts concerning the dentition are furnished by the fragment of jaws from the London Clay of Sheppey shown of the natural size in Fig. 12. The specimen is a lump of indurated clay displaying the anterior or symphysial end of both jaws, with the teeth slightly displaced and obscured. The foremost teeth of the right side of the lower jaw (*md.*) are best seen. The first tooth (I) is not smaller than the second (II), but it exhibits a somewhat narrower crown than the latter, with the sharp lateral edges not extending quite to the rounded base, and the lateral denticles extremely minute. In No. II larger lateral denticles are associated with the broader crown. The third tooth (III) has lateral denticles resembling those of No. II, and the crown seems to be slightly smaller and less elevated; but the matrix partly obscures the fossil. Portions of successors of each of these teeth project from the matrix. Below the next similar tooth (IV) there is displaced a diminutive tooth (*x*), pointing downwards, which probably occupied the gap between the third and fourth large upper teeth always observable in *Odontaspis*. This small tooth (*x*) is here noteworthy for its short, broad crown and relatively large, broad lateral denticles. In the fourth tooth (IV) of the mandible the slender lateral denticles are still more conspicuous than in the others, and, so far as can be judged from its exposed basal portion, the crown seems to be less elevated. The teeth of the upper jaw (*u*) are unfortunately shown only by the roots, and thus cannot be satisfactorily examined.

3. *Odontaspis elegans*, Agassiz sp. (Pl. I, Figs. 15—18). The name *Lamna elegans* is commonly given to every *Odontaspis*-like tooth from the Eocene formations which exhibits longitudinal striations on the inner or convex face of the crown. The latest researches, however, seem to the present writer to suggest that two species of *Odontaspis* are confounded under this familiar denomination. In the British Museum Catalogue (Pt. I, p. 362) it was remarked: "Among the specimens originally assigned to this species by Agassiz are three teeth (*op. cit.*, Pl. XXXV, Figs. 6, 7; Pl. XXXVII*a*, Fig. 58) which appear to be truly referable to *Lamna* (*Otodus*) *macrota*." Quite lately, after a study of new

specimens from the Lower Tertiaries of Russia, Dr. Jaekel* has adopted the still bolder course of referring the so-called *Otodus macrotus* of Agassiz to *Odontaspis*, observing that its front teeth "were somewhat later described as *Lamna elegans*" (*loc. cit.*, p. 30). A careful re-consideration of the whole subject seems to show that this course will prove correct. Probably all the teeth figured by Agassiz under the name of *Lamna elegans*, on Plates XXXV and XXXVII*a* of his volume already cited, are the front teeth of the shark which must henceforth be known as *Odontaspis macrota*. One tooth, however, similarly named by Agassiz (*tom. cit.*, p. 369, Pl. XL*b*, Fig. 24) from the London Clay of Sheppey, appears to be much too slender for reference to the latter species; and as this is of a type universally termed *elegans*, it will cause least confusion in nomenclature to retain the name for such teeth. This is the sense in which it is adopted by Noetling in an elaborate memoir on Selachian remains from the Upper Eocene of North Germany,† in which the author attempts to identify teeth from different parts of the jaw. The anterior teeth (Figs. 15–17), according to this arrangement, exhibit a very high and narrow crown, only slightly curved, with the inner face strongly striated longitudinally, and scarcely flattened in the middle. They bear a single pair of small, prickle-like lateral denticles, and the nutritive foramen on the prominent inner side of the root is placed in a deep cleft. The lateral teeth (Fig. 18) have an almost equally slender, but less elevated, crown, which is similarly striated and flanked with relatively large, slender denticles. While the lateral teeth are thus readily distinguished from those of *O. macrota*, the anterior teeth cannot always be separated; and in some cases the naming of the specimens will be entirely uncertain. The narrowness of the crown and the intensity of the striation of the inner face must be regarded as specially characterising the front teeth of *O. elegans*, which also seems to have been a smaller species than *O. macrota*.

4. *Odontaspis macrota*, Agassiz sp. (Plate I, Figs. 19, 20). The typical lateral teeth of this species (Fig. 20) are much compressed, the crown with sharp cutting edges and a faintly-striated inner face; they bear a single pair of "broad-ear"-shaped large lateral denticles, which are usually rounded, though sometimes obtusely pointed—a feature referred to in the specific name. The front teeth (Fig. 19) are also much compressed, and the striæ on the inner face of the crown are fainter, more wavy and interrupted than those of the smaller, stouter teeth to which it is proposed to restrict the name *O. elegans*. It is still uncertain whether this species occurs in the London Clay, labels in collections being not always reliable; but it is a characteristic fossil of the Bracklesham

* O. Jaekel, "Unter-Tertiäre Selachier aus Südrussland," *Mém. Comité Géologique, St. Petersburg*, vol. ix, No. 4 (1895).

† F. Noetling, *Abh. Geol. Specialk. Preussen u. Thüring. Staaten*, vol. vi, Pt. 3 (1885), p. 61, Pl. IV.

Beds and Barton Clay, and one tooth is recorded from the Bagshot Beds of Colesworth, near Woking. The type specimens were obtained from the Calcaire Grossier of the Paris Basin.

Genus Lamna.

If *Lamna macrota* be removed to *Odontaspis*, the only teeth from the English Eocene which still seem to be undoubtedly referable to *Lamna*, are certain small forms from the London Clay, Bracklesham Beds, and Barton Clay, which are identifiable with the so-called *Otodus vincenti* of Winkler from the Bruxellian Beds of Belgium. At least, in the deposits where they occur both in this country and in Belgium, it is not yet possible to recognise any *Odontaspis*-like teeth which might be assigned to the symphysis of the same jaw. They are much compressed (Figs. 21, 22), the crown very acute, with sharp edges, and smooth inner face; and they bear a single pair of broad, well-separated, acuminate lateral denticles, flanked in the side teeth by a minute outer pair.

Genus Otodus.

The name *Otodus* was given by Agassiz to numerous teeth, which are now readily recognised as belonging either to *Odontaspis* or to *Lamna*. The very robust teeth commonly ascribed to the first-described or type species, however, have so peculiar an aspect that the generic name may well be retained for these until the fishes to which they belong are known. The latest researches suggest that they truly represent two forms.

1. *Otodus obliquus*, Agassiz. These very stout teeth attain a large size, the crown sometimes being five centimetres in height; and a good series from different parts of the mouth is figured by Agassiz. The crown is moderately compressed and always sharply pointed, smooth on its convex inner face, and without folds at the base. There is a single pair of broad, bluntly-pointed lateral denticles, frequently showing a tendency to sub-division. The inner face of the root is prominent, and the nutritive foramen is not sunk in a groove, Except that the edges of the crown are never distinctly serrated, these teeth closely resemble those of certain species of *Carcharodon*, and Noetling has actually proposed to refer them to the latter genus. They are commonest in the London Clay, but also occur in the Bracklesham Beds and Barton Clay.

2. *Otodus trigonalis*, Jaekel sp. (Pl. I, Figs. 23, 24). It has hitherto been the custom in England to refer the small teeth of the forms represented in Pl. I, Figs. 23, 24, to young individuals of *O. obliquus*.* Dr. Jaekel, however, has lately separated certain Russian teeth of the same character and proportions under the

* See F. Dixon, "Geology and Fossils of Sussex," Pl. X, Figs. 33, 34.

new name, *Hypotodus trigonalis.** They are of much smaller size than those of *O. obliquus*, and the lateral denticles are less developed, being merely a pair of small, slender cusps, usually flanked again by a pair of minute points. The inner face of the crown is smooth, and the nutritive foramen of the root is placed in a shallow groove. These teeth have the same geological range as those of *O. obliquus*; but as there are no known teeth distinctly intermediate between the two forms, it seems likely that they belong to a distinct and smaller species. No sufficient reason, however, has been mentioned for placing them in another genus, and they may, therefore, be known as *Otodus trigonalis.*

GENUS **Oxyrhina.**

Considering the abundance of the teeth of *Oxyrhina* in the Cretaceous, Miocene, and Pliocene formations, it is curious that they are scarcely known in the Eocene. The present writer is only acquainted with the two diminutive English specimens represented in Pl. I., Figs. 25, 26. These were originally described as the type specimens of *Carcharias* (*Scoliodon*) *eocænus*†; but one of them has lately been sliced in a vertical direction to display the internal structure, which definitely places it in the family Lamnidæ. The teeth being compressed, with smooth edges, and no lateral denticles, fall within the genus *Oxyrhina*, and must be provisionally known as *O. eocæna.* They are evidently referable to the side of the upper jaw, and are quite distinct from the equally small but comparatively slender teeth of the same genus from the Eocene of Belgium, named *O. nova*, Winkler, and *O. winkleri*, Vincent.

GENUS **Carcharodon.**

The teeth of *Carcharodon* resemble those of *Oxyrhina* and also of the so-called *Otodus*, except that the edge of the compressed crown is serrated. There are thus some forms without lateral denticles, others with a single pair.

1. *Carcharodon subserratus*, Agassiz. Only one tooth of this genus without lateral denticles, has hitherto been found in the Eocene. It was obtained from the London Clay of Sheppey, and described by Agassiz under the name of *C. subserratus.* It is a much compressed tooth, the crown measuring 0·025 m. in height, and 0·021 m. across the base, with very feeble and irregular serrations. Its root is partially corroded and destroyed.

2. *Carcharodon auriculatus*, Blainville sp., var. *toliapicus*, Agassiz. The Eocene teeth of *Carcharodon* with lateral denticles, are also of comparatively small size, and at first sight they are distinctly suggestive of the so-called *Otodus obliquus*,

* O. Jaekel, *op. cit.*, 1895, p. 32, Pl. I, Figs. 6, 7.
† A. S. Woodward, "Catal. Foss. Fishes B.M.," Pt. I. (1889), p. 436.

only differing in the presence of serrations. There seems, however, to be every gradation between these teeth and the comparatively large teeth of the Miocene and Pliocene named *C. auriculatus* or *C. angustidens*. They must therefore be regarded as merely a diminutive, early variety of the latter. One tooth, said to have been obtained from the London Clay, was described by Agassiz, under the name of *C. toliapicus*; and some from the Bracklesham Beds were identified by Dixon with the so-called *C. heterodon*, Agassiz, which is evidently synonymous.

FAMILY *CARCHARIIDÆ.*

The Carchariidæ are almost, if not exclusively, a Tertiary family of predaceous sharks, with the teeth much resembling those of the Lamnidæ, but differing in their internal structure. These teeth are hollow throughout life, and minute tubules radiate from the central cavity across the dentine.

Many existing genera are recognised, but most of them can scarcely be distinguished on the evidence of detached teeth. The shape of the teeth, indeed, is much less distinctive of the various genera even than in the Lamnidæ. Several English Eocene specimens in the British Museum seem to represent some of the sub-genera of *Carcharias*, and one tooth from the London Clay, named *Glyphis hastalis* by Agassiz, may belong to the same genus; but *Galeus* and *Galeocerdo* seem to be the only forms recognisable with tolerable certainty. The complete fishes known from the Upper Eocene of Monte Bolca, are more or less closely related to the latter genera.

GENUS **Galeus.**

The small compressed teeth of this genus are known both from the London Clay (Pl. I, Fig. 28) and from the Barton Clay (Fig. 27), and are almost identical with those of the existing *G. canis.* The crown is not serrated, its apex is turned backwards, and below the notch in its posterior margin there are a few denticulations. The so-called *Galeocerdo minor*, Agassiz (Pl. I, Figs. 29, 30), from the London Clay and Barton Clay may also perhaps belong to this genus. The teeth thus named exhibit denticulations at the base of the crown, both in front and behind —a condition observable in certain teeth of the existing species already mentioned.

GENUS **Galeocerdo.**

The teeth of *Galeocerdo* are serrated on both margins, with a deep notch in the posterior margin, and the apex more or less sharply inclined backwards. They are almost similar in both jaws, and vary very little in different parts. Characteristic examples of one species, *G. latidens*, Agassiz, occur in the Bracklesham Beds (Pl. I, Figs. 31, 32). These teeth are remarkably low and broad, with very prominent serrations.

It will be convenient, in conclusion, to append a list of the species of Selachian teeth now recognised in the English Eocene formations, with a statement of their known range. There is much still to be learned on the latter subject, and careful collecting by stratigraphical geologists, familiar with the deposits, is perhaps the next most desirable mode of research for the advancement of our knowledge of the fishes to which the teeth belong.

ALPHABETICAL LIST OF ENGLISH EOCENE SELACHII WITH KNOWN STRATIGRAPHICAL RANGE.

	Thanet Sands.	Woolwich & Reading Beds.	London Clay.	Bagshot Beds.	Bracklesham Beds.	Barton Clay.
Acanthias orpiensis, Winkl. sp.	...	×	...	...	...	...
Aetobatis irregularis, Ag.	...	...	×	...	×	×
„ *marginalis*, Ag.	...	...	...	...	×	...
Carcharias (*Glyphis*) *hastalis*, Ag.	...	...	×	...	...	...
Carcharodon auriculatus, Blv. sp var. *toliapicus*, Ag.	...	...	(?)	...	×	×
Carcharodon subserratus, Ag.	...	...	×	...	...	...
Cestracion, sp.	...	×	×	...	...	...
Galeocerdo latidens, Ag.	...	...	...	...	×	...
„ (?) *minor*, Ag.	...	...	×	...	...	×
Galeus, sp.	...	...	×	...	...	×
Lamna vincenti, Winkl. sp.	...	...	×	...	×	×
Myliobatis dixoni, Ag.	...	...	...	...	×	×
„ *goniopleurus*, Ag.	...	...	×	...	×	...
„ *latidens*, A.S.W.	...	...	...	...	×	...
„ *striatus*, Buckl.	...	...	...	...	×	×
„ *toliapicus*, Ag.	...	...	×	...	×	×
Notidanus primigenius, Ag.	...	...	...	...	...	×
„ *serratissimus*, Ag.	...	...	×	...	...	...
Odontaspis cuspidata, Ag.	×	×	×	...	×	×
„ *elegans*, Ag. sp.	×	×	×	×	×	×
„ *macrota*, Ag. sp.	...	...	(?)	×	×	×
„ *rutoti*, Winkl. sp.	×	...	...	...	...	...
Otodus obliquus, Ag.	...	...	×	...	×	×
„ *trigonalis*, Jaek. sp.	...	...	×	...	×	×
Oxyrhina eocaena, A.S.W.	...	...	×	...	...	...
Pristis bisulcata, Ag.	...	...	...	...	×	×
„ *contorta*, Dixon	...	...	...	...	×	...
Rhinoptera daviesi, A.S.W.	...	...	×	...	...	...
Squatina sp.	...	×	×	...	...	...
"*Xiphodolamia*" sp.	...	...	×	...	...	...

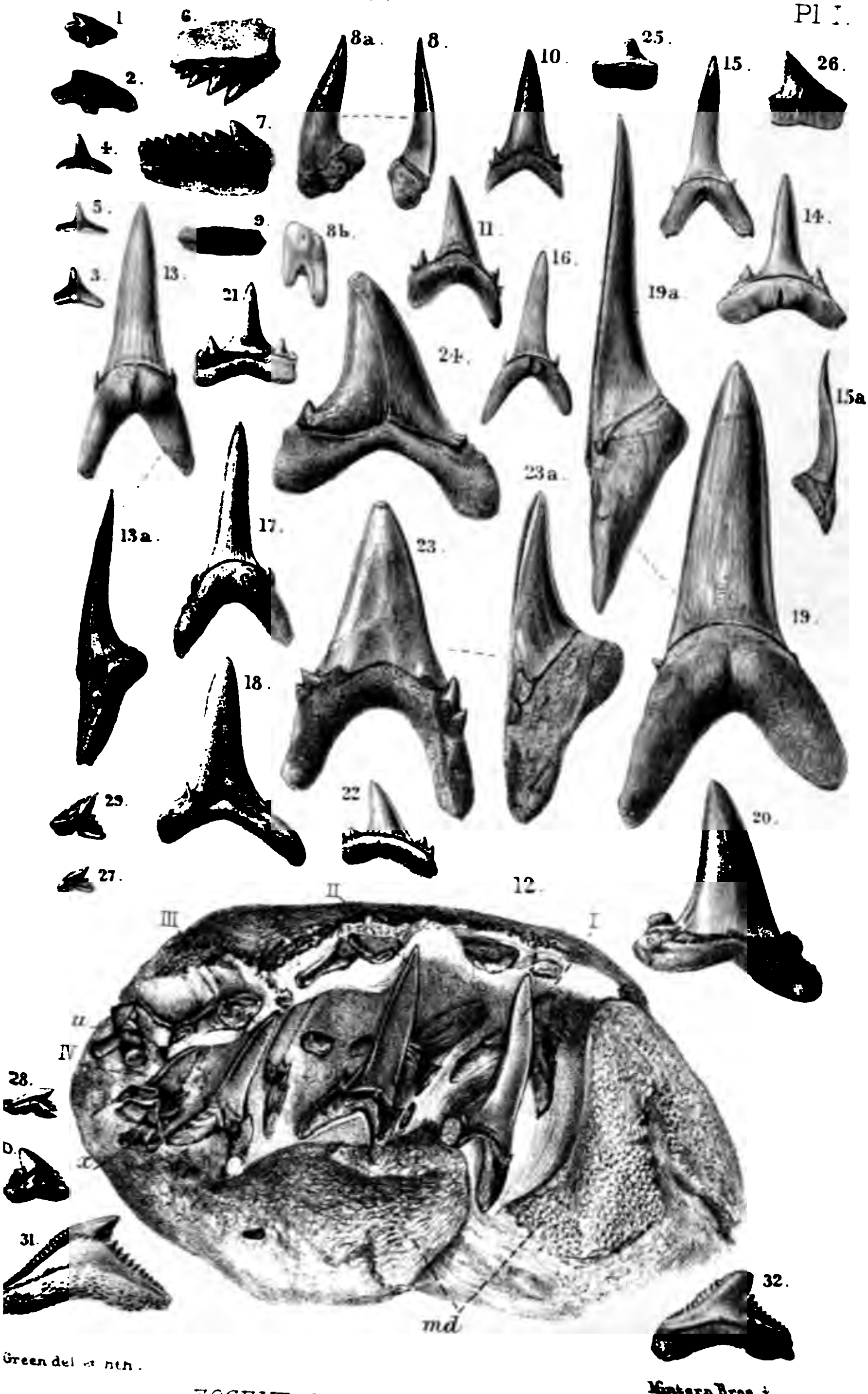
EXPLANATION OF PLATE I.

FIGS. 1, 2.—*Acanthias orpiensis* (Winkler); two teeth from outer and inner aspect respectively.—Woolwich and Reading Beds; Chislehurst. [P. 4104.]

FIG. 3.—*Squatina* sp.; tooth, inner aspect.—*Ibid.* [P. 4104*a*.]

FIGS. 4, 5.—*Squatina* sp.; two teeth, outer aspect.—London Clay; Highgate Archway. [43135.]
FIG. 6.—*Notidanus serratissimus*, Ag.; upper tooth, inner aspect.—London Clay; Kensal Green. [43142.]
FIG. 7.—Ditto; lower tooth, outer aspect.—London Clay; Sheppey. [Mus. Practical Geology, No. 6474.]
FIGS. 8, 8*a*, 8*b*.—*Xiphodolamia* sp. (supposed anterior upper tooth of *Notidanus*); side view, oblique outer view, and lower aspect of base.—*Ibid.* [43141.]
FIG. 9.—*Cestracion* sp.; tooth, coronal aspect.—London Clay; Highgate Archway. [43136.]
FIGS. 10, 11.—*Odontaspis rutoti* (Winkler); anterior and lateral teeth, outer and inner aspect respectively.—Thanet Sands; Reculvers. [P. 4102.]
FIG. 12.—*Odontaspis cuspidata*, Ag.; anterior end of jaws with teeth, outer aspect.—London Clay; Sheppey. *md.*, mandible; *u*, upper teeth; *x*, supposed small upper tooth; I—IV, anterior lower teeth. [28763.]
FIGS. 13, 13*a*.—Ditto; anterior tooth, inner and lateral aspects.—Lower Eocene; Portsmouth. [P. 5512.]
FIG. 14.—Ditto; lateral tooth, inner aspect.—Headon Beds; Headon Hill, Isle of Wight. [40240.]
FIG. 15.—*Odontaspis elegans*, Ag.; anterior tooth, inner aspect.—London Clay; Highgate. [20205*.]
FIG. 16.—Ditto; anterior tooth, inner aspect.—London Clay; Sheppey. [28887.]
FIGS. 17, 18.—Ditto; anterior and lateral teeth, inner (abraded) and outer aspect respectively.—Barton Clay; Hampshire. [40228.]
FIGS. 19, 19*a*.—*Odontaspis macrota*, Ag.; anterior tooth, inner and lateral aspects.—Bracklesham Beds; Sussex. [25683.]
FIG. 20.—Ditto; lateral tooth, outer aspect.—*Ibid.* [25686.]
FIG. 21.—*Lamna vincenti* (Winkler); tooth, outer aspect.—Barton Clay; Hampshire. [40244*a*.]
FIG. 22.—Ditto; tooth, inner aspect.—London Clay; Highgate. [43132.]
FIGS. 23, 23*a*.—*Otodus* (*Hypotodus*) *trigonalis* (Jaekel); anterior tooth, outer and lateral aspects.—Bracklesham Beds; Sussex. [P. 1167.]
FIG. 24.—Ditto; lateral tooth, outer aspect.—Lower Eocene; Portsmouth Docks. [P. 5506.]
FIGS. 25, 26.—*Oxyrhina eocæna* (A. S. Woodw.); two teeth, inner and outer aspect respectively.—London Clay; Highgate. [43135.]
FIG. 27.—*Galeus* sp.; tooth, outer aspect.—Barton Clay; Hampshire. [40242*a*.]
FIG. 28.—*Galeus* sp.; tooth, inner aspect.—London Clay; Highgate. [43134*a*.]
FIG. 29—*Galeocerdo* (?) *minor*, Ag.; tooth, outer aspect.—*Ibid.* [43134.]
FIG. 30.—Ditto; tooth, inner aspect.—Barton Clay; High Cliff, Hampshire. [40245.]
FIGS. 31, 32.—*Galeocerdo latidens*, Ag.; two teeth, inner and outer aspect respectively.—Bracklesham Beds; Sussex. [25677.]

All the figures are of the natural size. Except the original of Fig. 7, all the specimens are preserved in the British Museum, and bear the Register numbers placed in square brackets.



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EOCENE SELACHIAN TEETH

CONTRIBUTIONS TO THE GEOLOGY OF THE THAME VALLEY.

By A. M. DAVIES, A.R.C.S., B.Sc., F.G.S.

(Read December 2nd, 1898.)*

[*PLATE II.*]

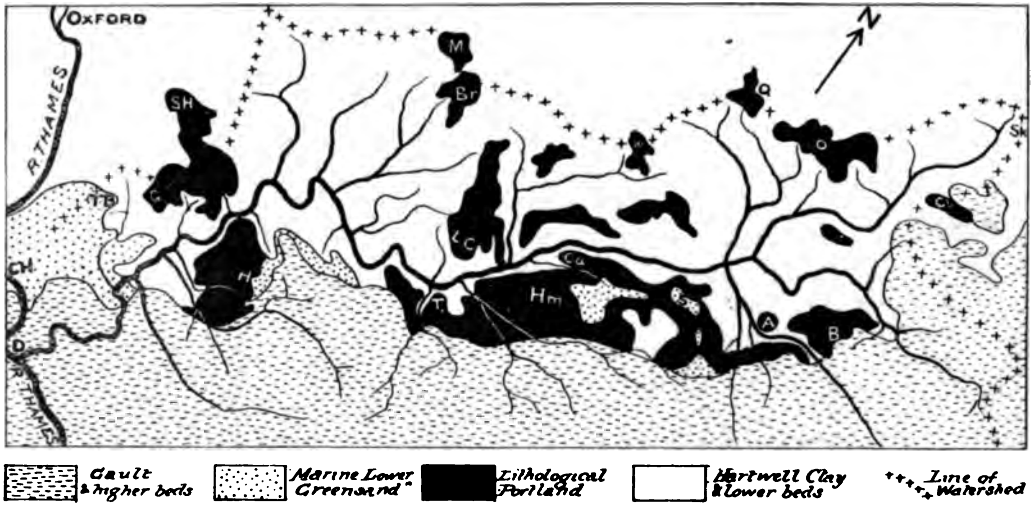
I.—INTRODUCTION.

THE Thame is, broadly considered, a longitudinal or "subsequent" tributary of the Thames, draining the region at the foot of the Chalk escarpment of the Chilterns. The area drained by it is roughly an oblong, about twenty-five miles in length from N.E. to S.W., in the general direction of the strike of the strata, and varying from ten to twelve miles in breadth from N.W. to S.E., or in the general direction of dip. Its south-eastern boundary is the crest of the escarpment of the Chilterns, which maintains a steady height of from 700 to 800 feet above sea-level, except where beheaded valleys reduce it to nearly 400 at Saunderton, Wendover, and Tring. Its north-eastern boundary runs in an irregular manner from near Tring to Stewkley, and does not rise much above or fall much below 400 at any point. The north-western boundary is much more irregular, both in direction and in level, rising to over 600 at Quainton, Brill, and Muswell Hills, and over 400 in the high ground about Wheatley, and falling to about 250 in the low areas that alternate with the hills. (See fig. 1).

The region thus defined geographically is no less clearly marked geologically. It is sharply distinguished by a double peculiarity in geological structure from the adjoining areas on the same line of strike. The first difference is that the sandy beds below the Gault, commonly termed "Lower Greensand," have a broken and irregular outcrop. The second is the presence of higher Jurassic beds—beds, moreover, of sandy and calcareous, instead of the predominant clayey, character. The abundance of outliers may be said to constitute a third distinction.

The course of the Thame itself is interesting. It flows over clay ground for practically its whole course, some of its headwaters and its final five miles or so being on Gault, while the whole intervening portion is on Upper Jurassic (Kimeridge) Clay. Between the points at which it leaves and re-enters the Gault area, the stream falls just 100 feet—from about 270 to about 170 feet above O.D. At both these points the two clays are either in direct superposition or have only a small thickness of

* Some slight additions have since been made, and certain parts omitted.



Purbeck and Freshwater " Lower Greensand " not marked.

FIG. 1.—KEY-MAP OF THE THAME VALLEY.

(From the Geological Survey Index Map, Sheets 11 and 12, with alterations.)

Scale—1 inch to 5 miles.

A	Aylesbury	CH	Clifton Hampden	LC	Long Crendon	SH	Shotover Hill
B	Bierton	D	Dorchester	M	Muswell Hill	Sk	Stewkley
Br	Brill	G	Garsington	O	Oving	T	Thame
Cb	Cublington	H	Great Hazeley	Q	Quainton Hill	TB	Toot Baldon
Cd	Cuddington	Hm	Haddenham	S	Stone	W	Waddesdon Manor

N.B.—The line of watershed should run through the Ashendon outlier, between Brill and Waddesdon.

intervening beds; whereas elsewhere in the district more than 100 feet of other strata intervene. Thus the geological structure of the district has modified the course of the Thame from that of a simple subsequent stream to a more complex form, to which I shall refer towards the end of the paper. The irregularity of the north-western watershed—unusual in a strike-boundary—is due to the same causes.

Although described by Buckland and Conybeare, and mapped by William Smith, the district first underwent a thorough examination by Fitton, whose observations are recorded in the classical memoir, "On the Strata between the Chalk and the Oxford Oolite" (*Trans. Geol. Soc.*, ser. 2, vol. iv, p. 163). Twenty years or more after Fitton, the Geological Survey examined and mapped the district, and their results appear on Sheets 13, 45 S.E. and 46 S.W., published in 1860, 1863, and 1865 respectively, and in the explanatory memoirs to the first two of these sheets, published in 1864 and 1861.

About the same period Prof. Phillips made a number of observations on the district, which are recorded in his "Geology of Oxford."

The chief railways in the Thame Valley were made very shortly after the completion of the Geological Survey—a fact much to be regretted, since the cuttings, though shallow, are numerous, and would have given valuable information had they been properly studied. Now they are all grass-covered, and I have only been able to discover geological references to two, other than those at Aylesbury (Codrington. *Quart. Journ. Geol. Soc.*, vol. xx, p. 374; Cobbold, *ibid*, vol. xxvi, p. 314).

During the next twenty years the district was chiefly studied by Prof. Morris, Mr. Hudleston, and Prof. Blake, each of whom has guided excursions of this Association to the district.*

More recently some revision of the area has been made by Messrs. A. C. G. Cameron, J. H. Blake and Jukes-Browne, for the Geological Survey, but the results are as yet only partially given to the public. Some observations on the Upper Jurassic rocks have, however, been made by Mr. H. B. Woodward, and are to be found in the Memoir on these rocks (Vol. V.), but the only account of the "Lower Greensand" is in the "Explanation of Horizontal Section Sheet 140," by Mr. Jukes-Browne. Considerable revision of the boundary lines seems, however, to have been made in the north-eastern part of the area, judging from the new Index Map.

The present paper records a series of observations made during the last two years in a number of visits to the district, and the conclusions based upon them. My original intention was to study a small part of the area only in greater detail, but the necessity of comparison soon led me over almost the whole

* See *Record of Excursions*; and *Proc. Geol. Assoc.*, vol. xiii, p. 71.

area. To map so large a district in detail would require years from a private worker who can only spare a few days now and then for the task. I have, therefore, attempted nothing so ambitious. Confining myself, for the most part, to the beds between the Kimeridge Clay and the Gault, I have repeatedly visited the outcrop and chief outliers of these beds, traversing them in many directions. I do not think I can have overlooked any important exposure, unless it be on certain outliers which I have not had time to visit. I have examined many of the rocks, microscopically and otherwise, at home.

In field-work, I need hardly say that I have derived the greatest possible assistance from the published maps of the Geological Survey. Although the existence of new exposures has in some cases enabled me to detect errors in the mapping, I am able to testify to their very great accuracy on the whole, especially in view of the fact that the area was surveyed before the six-inch maps were available.

I have to express my special thanks to Mr. J. H. Blake, who conducted me over the classical section of Shotover Hill; to Messrs. E. T. Newton and H. A. Allen of Jermyn Street Museum, and Messrs. R. B. Newton and G. C. Crick of the Natural History Museum, for great help in the identification of fossils; to Mr. F. Chapman, who has identified and supplied notes on all the Ostracoda and Foraminifera; to Prof. Bonney, who kindly enabled me to examine the late Prof. Morris's specimens at University College; and to my wife, who has drawn the maps and sections, and helped me in the field-work.

II.—PORTLAND BEDS.

The Portland Beds, or such part of them as is lithologically separable from the great clay-formation below, were divided by the Geological Survey into "Portland Sand" below, and "Portland Stone" above. This division does express the fact that on the whole sands predominate in the lower part and limestone in the upper; but Mr. Whitaker has referred to the difficulty in separating the two at many points. Mr. H. B. Woodward has shown that these two divisions here do not correspond in age with those so-named in Dorset. In fact, it is probable that the line between them, even where it can be satisfactorily drawn, does not represent a constant horizon throughout our district.

Similarly, the base-line of the "Portland Sands" does not represent a constant horizon, but as it is a very definite stratigraphical line, marked by a line of springs, I shall speak of the beds above it as the "lithological Portland," to avoid misunderstanding and needless complexity of phrasing.

Prof. J. F. Blake, in his paper on the "Portland Rocks of England" (*Quart. Journ. Geol. Soc.*, vol. xxxvi, p. 189) distinguished within the "Portland Stone" of this district an upper "Creamy Limestone" and a lower "Rubbly Limestone," separated by a bed of sand. These divisions hold for tne north-eastern part of the district, but I have not been able to recognise them in the central and south-western portions.

There are only three places in the district where I have found it possible to obtain a tolerably complete section down to the top of the clay series, namely, Garsington, Long Crendon, and Dadbrook Hill (between Haddenham and Cuddington). A fourth section, that of Stone and Hartwell, has been already determined by Messrs. Hudleston, Blake, and H. B. Woodward. These four sections are indicated in Plate II, and it will be convenient to consider the Portland Beds in each of them before going on to a general description.

(a) Garsington Section.

When Dr. Fitton visited the district there seem to have been many stone-pits here, since he says that the *principal* ones are in the western escarpment of the hill, overlooking the low ground about Langcomb and Cowley. Now, however, the stone-pits seem all abandoned and mostly levelled over; the only one I saw was being used to store Leicestershire road-metal. Still, a number of small roadside exposures are available, and with the help of the six-inch map and a reflecting level I have been able to piece together a tolerably complete section.

The lowest beds are best exposed in the cuttings of the Oxford road as it mounts the hill from Kiln Farm into Garsington village. Clay is seen exposed at intervals almost up to the little stone-quarry mentioned above, which must expose almost the very base of the lithological Portland. The presence of a series of springs at about 340 feet above O.D. marks this as the level of the top of the clays. In the quarry itself there are exposed :

	ft.	in.
3. Pale bluish-green and grey sands		9
2. Shelly sands passing down into sandy limestone ...	1	0
1. More massive limestone	3	6

There seems to be a rapid lateral change in Bed 2, but it is not easy to trace it. Above the level of the quarry and farther back from the road, a fine vertical face of pale yellowish sand about 15 feet high is exposed. Thus here we have "Portland Stone" at the very base of the "Portland Sand." The pale sand can be traced in the road-cutting from here nearly up to the "Red Lion," and two courses of stone occur in it, as shown in the section (Plate II). From this point the succession failed.

A more complete section can be made out on the other side of the hill, less than half a mile away. On the six-inch map a spring is marked a quarter-mile due south of City Farm. This fine spring is apparently thrown cut by the clay at the base of the Shotover Ironsands, and in the side of a steep bank. If one follows the path along the top of this bank and down the hill-slope beyond, a trench is seen to run straight alongside the field-boundary. This trench had only been dug quite recently when I visited the spot last November, and clearly exposed the beds for a thickness of about 60 feet on both sides of the little valley, and although neither top nor bottom of the lithological Portland is shown, the position of these can be judged from surface indications. The Portland Sand is seen to a thickness of about 35 feet; towards the base it becomes clayey, and the basal limestone of the previous section seems to be absent. The sand is topped by a pebble-bed a few inches thick, full of pebbles of various shapes and sizes, but all well-rounded, and mostly between $\frac{1}{4}$-inch and $1\frac{1}{2}$ inches in length. Some of these are of quartz, but the majority are of black material, which one is apt to dismiss as "lydite." Careful examination, however, shows the latter name to cover a variety of materials; most of them are black chert, but among them I found several pebbles of spherulitic felsite and one of phosphatised bone.

Immediately above the pebble-bed, limestone begins and continues for about 12 feet; the basal part is very glauconitic and pebbly, and casts of *Cardium dissimile* are seen. Above come 9 feet of sand again, with one thin course of stone. After this the section becomes obscure, but there is evidence of more limestone, and then of the Shotover Ironsands at the top.

The Garsington section in Plate II was drawn up (so far as the Portland beds are concerned) from these two sections in combination, the details of the lowest 25 feet above the clay being taken from the road-section on the west of the village, and the remainder from the trench-section. The complete section is therefore a generalised one.

(b) Long Crendon Section.

Long Crendon is eight miles from Garsington, nearly along the line of strike. For six of those miles no Portland beds are exposed. Here again the section is pieced together from the exposures along several roads down the hill-side, but we have in addition a number of sand and stone pits and a brickfield. The last is at the foot of the hill by the side of the road to Thame, and was visited—or, at least, noticed—by the Association under Prof. Blake's guidance, in 1893. Prof. Blake then referred to the clay in the brickyard as Hartwell Clay, and it is also so referred

to by Mr. H. B. Woodward in his memoir, but I am not aware that Hartwell fossils have been found in it. I have found none, and a workman I spoke to said that none were found, though he certainly knew what fossils were. Its top is marked by a line of springs, the Lion Spring near the brick-kiln being one, at 272 feet above O.D., while another in Sandy Lane, a little over half a mile to the north-west, is rather above the 300 ft. contour.

The lowest bed of the lithological Portland, resting directly on the clay, is a bright green sand.

The upward sequence may be traced with tolerable completeness on the ascent from the Lion Spring to the village, and confirmed in Sandy Lane. We find some 30 feet of light-coloured sandy beds, in which there occur several beds of clayey sand. The lowest 11 feet or so is not exposed (except for the green sand above mentioned), but above this 5 feet of clayey sands are shown in a pit in Sandy Lane, and the presence of the same in the main road above the Lion Spring seemed to be shown by the presence of water at the bottom of a sand-pit there. In both sand-pits we next find the characteristic pale sands of the Portland, with a few lydite pebbles here and there, and with much clayey material in some beds; and in the pit by the main road we see, near the top, a laminated clayey sand full of lydite pebbles. This agrees closely in position with the pebble-bed of Garsington.

Continuing up the main road above the sand-pit, the road cutting shows a great amount of limestone, with indications of intercalated sand-beds here and there. At the point marked "Kiln" on the six-inch map, there is a small section as follows:

SECTION AT "THE KILN," ON THE ASCENT TO LONG CRENDON FROM THE LION SPRING.

	ft.	in.
5. Soil	1	6
4. Thin-bedded limestone	0	4
3. Calcareous loam	0	6
2. Rubbly limestone ... ... about	5	0
Another section a few yards to the north shows below the rubbly limestone:—		
1. Massive limestone with "*Amm. giganteus*,"* *Trigonia*, *Cardium*, etc.	10	0

Through the village of Long Crendon itself the ground is comparatively level, and though there are occasional exposures, the sequence cannot be followed. When we reach the more southern of the two windmills, a valuable section of the top beds is exposed, and allowing for the slight dip, it seems probable that only 5 or 6 feet intervene between the highest beds seen in the last section and the lowest seen in this one.

* The large ammonites commonly referred to by this name are probably in all cases in this district *Perisphinctes boloniensis*, De Lor. as Prof. Blake has pointed out.

SECTION AT SOUTHERN WINDMILL, LONG CRENDON.

		ft.	in
GAULT.	9. Clay with *Inoceramus concentricus*, *Belemnites minimus* and Foraminifera ...	8	0
? SHOTOVER IRONSANDS.	8. Sand, with pebbles of quartz and lydite, and ironstone-concretions containing calcite ...	1	6
	7. Green sandy clay	1	6
	6. Ironstone	0	6
	5. Bluish clay, black at base	0	6
PURBECK.	4. Limestone with clay-veins	4	6
	3. Pale clay, with Ostracods	1	0
	2. Crumbly calcareous sandstone	0	5
PORTLAND.	1. Massive blue-hearted limestone	3	6

This pit may be the actual one visited by the Association under Prof. Blake's guidance in 1893, but I suspect that that was another one some seventy yards farther west, which has been closed during the last eighteen months. The two sections differed only in slight details (mainly in the Shotover Ironsands).

The generalised section pieced together from these exposures is shown in Plate II. It agrees generally with that given in the memoir on the Jurassic rocks and that of Fitton, but differs in some details, due undoubtedly to variations in the strata from point to point. Thus Fitton found the pebble-bed immediately below a sandy and glauconitic limestone, and H. B. Woodward notes a pale-grey and greenish marl with *Trigonia gibbosa*, etc., as the top Portland bed, and $3\frac{1}{2}$ feet of calcareous sandstone within the upper blank space in my section.

(c) Haddenham (Dadbrook Hill) Section.

The Dad Brook is a small tributary of the Thame, which has cut a steep-sided valley north of and nearly parallel to the main Thame-Aylesbury road. The road from Haddenham to Cuddington crosses this main road at a point known as the King's cross-roads or King's Cross, and then crosses the valley of the Dad Brook at right angles (see Map, p. 54). The steep slope down from the plateau on the south side of the valley is called Dadbrook Hill on the maps; it lies three miles E.N.E. from Long Crendon. As it is only a mile N. of the important village of Haddenham, and almost entirely within the parish of that name, I give that name to the section.

About 150 yards west of King's Cross, a small quarry has been opened in a field. I shall describe this section in detail later on (p. 40) in connection with the Purbeck beds, of which some 9 feet or more are exposed, with 3 or 4 feet of Portland Limestone below. In July, 1898, the ditch alongside the steepest part of the road down Dadbrook Hill had been freshly trenched,

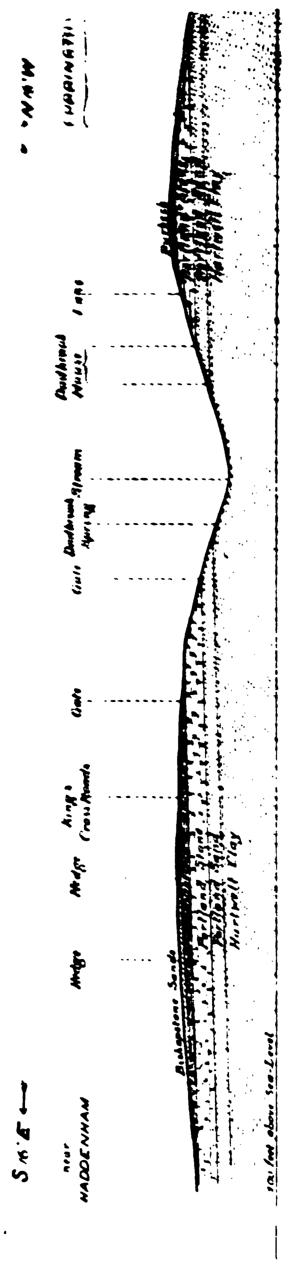


FIG. 2.—SECTION FROM NEAR HADDENHAM TO CUDDINGTON (BUCKS.).

Horizontal Scale - 6 inches to 1 mile. Vertical Scale—1 inch to 176 feet (5 times the horizontal scale).

The exact line of section is marked on the map (p. 54). Purbeck Beds are here shown as re-appearing from under the Bishopstone Beds at the left-hand end of the section, on the supposition of a uniform dip; there is no evidence of their presence on the ground, nor any clear evidence to the contrary.

and in it beds of limestone, sand, and clay were clearly exposed. By means of these two sections and various isolated exposures on the north side of the valley and elsewhere, I was able to plot out the section across the valley (Fig. 2) and the vertical section (Plate II).

The clay at the base is somewhat sandy and micaceous; I have found no fossils in it. At its junction with the sand above, a spring occurs which seems to have attained some small fame as a chalybeate spring. The point marked "Dadbrook Spring" on the six inch map is, however, some twenty yards north of the actual junction, and indicates the position of a little brick structure in which the water is received. Last September this spring was quite dry.

At the junction of the sand and clay some lydite pebbles occur, though not very abundantly. The sand itself is the usual pale yellow sand, with occasional glauconite grains, so characteristic of the Portland beds. A bed of limestone, 10 or 11 inches thick, occurs in it $5\frac{1}{2}$ feet from the base, and at a height of 12 feet above the base, limestone follows and apparently continues up to the base of the little

quarry, though the evidence of this is incomplete, and it is quite possible that some alternations of sand may occur.

(d) Stone and Hartwell Sections.

The remaining section on Plate II is simply a copy of one already published by Mr. H. B. Woodward, so far as the Portland and Purbeck Beds are concerned; the Bishopstone Beds are inserted from my own observations. Mr. Woodward's section appeared in the Memoir on the Jurassic rocks and has been repeated in our PROCEEDINGS (vol. xv, p. 93) as a "General Section at Aylesbury." The main details, however, are derived from the Bugle Pit, which is in the parish of Stone, 2 miles S.W. of Aylesbury, and $3\frac{1}{2}$ miles N. by W. from Dadbrook Hill. The Windmill Pit, from which most of the details of the Bishopstone Sands are taken, is also in the parish of Stone, nearly one mile farther west, and this section lies almost exactly in a straight line from Garsington through Long Crendon and Dadbrook Hill to Aylesbury, being $2\frac{1}{2}$ miles from the last and $2\frac{3}{4}$ miles from the last but one of these places.

Mr. Woodward's section is fully explained in his memoir, and more briefly in our PROCEEDINGS lately, so that I need not say more on it here.

To complete this set of vertical sections I should like to have added a fifth, dealing with the sequence to the north, either on Quainton Hill or at Oving and Whitchurch. But the information I have been able to get there is not sufficient to allow me to plot out a section similar to the other four.

(e) Comparison of the Sections.

In comparing these four sections, the fact which strikes us first is the great difference in thickness between the lithological Portland of Garsington and Long Crendon and that of Dadbrook Hill and Hartwell. The thickness in the two former cases is practically double that in the latter. How shall we explain this sudden change in thickness in the three miles between Long Crendon and Dadbrook Hill? In each case we have "Portland Sands" below and "Portland Stone" above; do these lithological names mean the same chronologically in the two cases? If they do, what is the explanation of this sudden change in thickness in both formations?

I do not think that the lithological divisions mean the same in the two cases. Mr. H. B. Woodward has called attention to the occurrence of a pebble-bed or lydite-bed as separating the Upper Portlandian from the Lower at Tisbury, Swindon, Bourton, and Brill, as well as at Aylesbury. Now, lydite and quartz-pebbles

occur at one level only in each of our four sections, and are quite restricted in their vertical range. If we take the pebble-bed in each case as a constant horizon, the difficulty as to the change in thickness vanishes, the "Portland Stone" of Garsington and Long Crendon being represented by *the whole of* the lithological Portland (Stone and Sand) of the easterly sections. Sand, indeed, is not wanting within the limits of the "Portland Stone" at Garsington. Again, if we consider the Lower Portlandian, or beds below the pebble-bed, we can trace a gradual transition, the clayey facies gradually rising from west to east. From the 39 feet of pure sands with limestone of Garsington, we pass through the 26 feet of more or less clayey sands of Long Crendon to the sandy clay of Dadbrook Hill and Hartwell. As a confirmation of this view we may note that at Scotsgrove Hill, 1¼ miles S.E. of Long Crendon and 2½ miles S.W. of Dadbrook Hill, the pebble-bed is seen with only 12 feet of sand below it, and with both limestone and sand above it. The pebble-bed also seems to have been noted at Great Hazeley by the Survey officers, at Cuddesden and Garsington by Prof. Blake, and is well known at Brill and Bierton, while the pebbly character of the beds in which the "Giant's marbles" occur on Shotover Hill may perhaps indicate the same horizon.

Since this paper was read, Mr. J. H. Blake, who has been mapping the western part of our district for the Survey, has kindly informed me of an exposure of a similar pebble-bed on the eastern slope of Shotover Hill, near the 400 feet contour.

There are certain general reasons why a pebble-bed of this kind should be a more trustworthy indication of a definite horizon than a line of lithological change. It must be remembered that this is a solitary bed of coarse material interpolated in the midst of a series of which the other beds are fine sands (the grains usually being about ·1 mm. in diameter), limestones, and clay. Such a bed, especially when continuous over a large area, betokens most probably an interruption of normal sedimentation for a time by the action of a current—some of the fine material previously deposited being probably swept away at the beginning of the current-phase, while at the end of that phase the first slackening in the current would cause a deposition of pebbles previously swept to and fro, and then the deposit of fine material would be resumed.

At Swindon, and in the Aylesbury district, phosphatised fossils have been found in the pebble-bed, and I have found one such fragment at Garsington. These are confirmatory indications that the pebble-bed indicates a period of current action and cessation of sediment.

Stratigraphically, therefore, the evidence for the view that the pebble-bed marks a constant horizon in our district is strong; but, to complete the proof, palæontological evidence is needful. This

I am, unfortunately, not able to supply at present. The Hartwell Clay contains an abundant and characteristic fauna, which proves it to be Lower Portlandian (Middle Portlandian of Continental geologists); but the sands below the pebble-bed at Garsington and Long Crendon are very unfossiliferous. The only fossils I found at Garsington were *Pleuromya tellina* (which ranges from Corallian to Upper Portlandian) and a cast of a large *Cardium*, very close to *C. dissimile*. This latter species is characteristic of the Upper Portland, but does occur in the Lower (according to the table in the Jurassic Memoir). On the other hand, the Hartwell Clay species of *Cardium* are small ones (*C. morinicum* and *C. striatulum*), and the large *C. dissimile* is unknown there. Until a larger collection of fossils has been made from the sands below the pebble-bed, the question cannot be taken as settled.

(f) General Account.

Let us now trace the outcrop and outliers of the lithological Portland from S.W. to N.E. through our district.

The westernmost point where Portlandian beds (other than Hartwell Clay) have been supposed to occur is at Toot Baldon, one mile S.W. of Garsington. The sands here have been mapped as Lower Greensand, but Phillips found near their base a pebbly bed with an Ammonite "of the group of *A. polyplocus*" (*i.e.* a *Perisphinctes*). This suggests Portlandian beds, but it is the only evidence for them. Exposures here are at present very poor, and I failed to find any fossils. I shall refer to these sands again in Part IV.

The undoubted Portland beds begin along a N.W.—S.E. line about a mile north-east of Toot Baldon. This line marks off the limit both of the main outcrop and of the large irregular outlier that forms the heights from Shotover Hill to Garsington, an outlier separated from the main outcrop by the Thame in cutting down its present valley.

SHOTOVER-GARSINGTON OUTLIER.—The Shotover Hill succession has been fully described by various authors, and I have nothing to add to the account in the Survey Memoir on the Jurassic Rocks. Coming to the south side of the railway, a good section of the upper part of the Portland was once exposed in the deep cutting of the road from Horsepath to near Combe Wood. This is figured and described in the Survey Memoir to Sheet 13. Though much obscured now, the succession of beds can still be made out in this section, and in addition to those figured, the "Portland Sand" can be seen a little lower down the road. At the foot of the hill sandy clay was exposed in a drain in connection with a new house being built on the north side of the road (September, 1898), and I measured the total thickness

of the lithological Portland here (by means of a reflecting level) as about 60 feet.

For a mile from here southward there are no good exposures, though signs of the old pits mentioned by Fitton may be detected, and the next one is in a hollow lane leading down from the main Wheatley—Garsington Road, south of City Farm, to Kiln Farm. The first furlong along this lane is level, and the soil in the fields is that of typical Shotover Ironsands. Then comes a rapid descent for 150 yards, and in the cuttings can be seen—first, ironsands; then a white plastic clay of the Shotover beds, doubtless the bed which throws out springs all along the line; then more ironsands, of no great thickness. Next comes a fine calcareous sand with concretionary lumps; below this is a calcareous glauconitic sandstone (or sandy limestone), then 4 inches of rubbly limestone with *Trigonia* casts, and below that a soft calcareous sand. From here downwards the section is much obscured by slip from the Shotover Ironsands, and the last-mentioned beds had their dip affected by the slip. I cannot feel sure, therefore, that the sandy limestone seen at two points a little lower down was really in place.

We now come to Garsington village, where the chief exposures have already been mentioned. Minor exposures of sand, with stone-beds, occur at several other points in the village. But in the road-cutting on the way to the Manor House there is seen a white clay, slightly calcareous, overlying typical pale yellowish sand. I am unable to place this clay anywhere in the Portland sequence: possibly it may have slipped here from the Shotover Beds. I obtained from it a single ostracod, identified by Mr. Chapman as *Metacypris* (?) *sp. nov.*

Following the outcrop northwards from the village, we pass the trench-section already mentioned (p. 20), and half a mile farther north-west, in a field one-third of a mile almost due south of the Horsepath Road cutting, we find, a little below the 400 feet contour, the following exposure:

SMALL FIELD-EXPOSURE ON CREST OF HILL ABOVE "LOWER BARN," NEARLY A MILE N.E. OF GARSINGTON.

	ft.	in.
5. Soil with limestone-rubble, indicating a higher limestone bed near by	0	7
4. Fine sand	0	2
3. Very calcareous sand	0	3
2. Buff sand, with very few glauconite grains	0	4
1. Hard calcareous sandstone, showing fine layers on weathered surface, but not fissile	1	7

A small digging just below shows pure yellow sands.

In Cuddesden village Portland Limestone crops out in the roadway; and less than half a mile north-east of it, alongside the footpath to "The Park" which runs parallel to the 300 feet contour, we find the following section:

SMALL QUARRY NEAR 300 FEET CONTOUR, ¼ MILE N.E. OF CUDDESDEN.

		ft.	in.
	6. Soil and rubble ... . about	1	0
SHOTOVER BEDS (?)	5. Beds of dark clay and sand, resting on irregularities in the bed below, varying from 0 to	5	0
PORTLAND BEDS.	4. Soft rubbly calcareous sandstone, with abundant casts of *Trigonia* (the uppermost 18 in. is in places a harder stone). Perhaps in part *remanié*. Thickness up to	6	0
	3. Harder, shelly calcareous sandstone (or sandy limestone) with abundant fossils—*Ostrea* ...	0	9
	2. Soft, crumbly calcareous sandstone	2	7
	1. Hard calcareous sandstone (or sandy limestone)	1	6

The lower part of the lithological Portland around Cuddesden seems to consist of rather clayey sands, as though the change that is seen at Long Crendon were already beginning to show itself; but there are no good exposures.

Continuing round the outlier, one finds on Castle Hill some indications of a greater development of the limestones, for in the ploughed fields about the 300 contour there are abundant fossils thrown up—*Cardium dissimile*, *Trigonia*, and a "gigantic" Ammonite.

We now arrive at the point where, on the Geological Survey Maps (including the recently-published Index Map, Sheet 11), the Shotover Beds ("Lower Greensand") are marked as overstepping the Portland to rest directly on the Kimeridge Clay. I am not prepared to assert that no such overstep exists, as I have not been over the whole ground in question. But at the point where it is shown as having its greatest extension, between Wheatley and Littleworth, I have found evidence of both "Portland Sand" and "Portland Stone," and I believe the apparent overstep to be due to extensive slips down the steep hillside.

The railway between Wheatley and the Horsepath tunnel cuts right through the supposed transgression, but the cutting is now obscured. Just south of the railway, however, large diggings of Kimeridge (or Hartwell?) Clay for brick-making have been made, and these show no sign of the ironsands in place above them. From the eastern end of the brickfield a footpath which has crossed the railway on the level leads up to Windmill Lane through ploughed fields and market-gardens. At first the soil is sandy, but about the 400 contour it shows such an abundance of limestone-fragments that it cannot be doubted that there is an actual outcrop beneath. From among these fragments I picked up a portion of an Ammonite (*Perisphinctes* probably *biplex*). The limestone continues nearly to the top of the path, where the ironsands are seen by the hedge.

Another footpath, more to the west, not marked on the six-inch map, leads from the hamlet of Littleworth obliquely up the hill and afterwards turns along the hillside to join the path just

described. Along the lower part of this some instructive openings can be seen. In one there are shown some five feet of typical pale "Portland Sands" with large calcareous concretionary masses, reminding one of those of Shotover Hill; but the sand-grains are much finer and the concretions not so hard. In these *Serpulæ* were abundant. Above these sands, ironsands and ironstone were seen; these may possibly be *in situ*, but I am strongly inclined to think that they have slipped down. It is difficult to fix the position of these exposures on the old one-inch sheet—the road by Littleworth has been shifted in the making of the railway—but it is possible that this is just the point where the last appearance of "Portland Sand" was shown by the Geological Survey. Certainly there is a profusion of "Lower Greensand" material in the soil from here eastwards, but in view of the limestone outcrop higher up the hillside, the absence of sands above the clay in the brickfield, and the steepness of the hillside with its structural suitability for slipping, it seems highly probable that the supposed overstep has no real existence.* This practically completes the "beating the bounds" of this large outlier.

MAIN OUTCROP, GREAT MILTON DISTRICT.—Through most of this area the slope of the ground is so gentle and the exposures are so small and scattered, that it is almost impossible to piece together the evidence into generalised sections, as I have been able to do at Garsington and Long Crendon. According to the published map, the Portland beds appear from under the overstepping Gault, about half a mile west of Stadhampton, and range northwards from this point above the left bank of the Thame to the valley of the small tributary that flows near Chilworth Farm. Near the source of this brook they are again overstepped by the Cretaceous beds. A second narrow outcrop, due to a strike-fault, extends for some way parallel to the Hazeley Brook, between it and the village of Great Hazeley. I have not verified the lower boundary-line, but have no doubt that it is substantially correct, though the very sandy nature of the material thrown out of the rabbit-burrows near Cuddesden Mill made me suspect that the line here should possibly have been drawn nearer the river. As regards the upper boundary, I think that too great a spread of "Lower Greensand" has been shown around Great Hazeley, for there seems to be Portland Limestone exposed in the roadway in the village, and in the little quarry by the church, described below, the limestone occurs immediately under the soil.

The best exposure of Portland beds in this district is the one at Great Milton, shown on the six-inch map, and described in the Memoir on the Jurassic Rocks (Vol. V, p. 219). As there is no essential variation in the face now exposed from that described

* At the meeting when this paper was read, Mr. H. B. Woodward announced that Mr. J. H. Blake had detected and corrected the error in the mapping here in 1897.

there, I need not insert a description here, though I shall have to refer to this pit again in connection with the "Lower Greensand." I have not been able, however, to verify the presence of *chert* in the sandy oolitic limestone here. There are certain concretionary-looking masses of darker colour in the rock, but they are calcareous; in fact, they are much purer limestone than the main rock, leaving only a slight residue of clayey material and very fine sand-grains when dissolved in acid.

A mile south-west of this exposure, near Little Milton village, a hundred and thirty yards along the main road south-west from the milestone marking sixteen miles from Aylesbury, a small opening exposes a thickness of 15 feet, now much obscured by slip and partly grassed over. All that can now be made out is about a foot of rubbly oolitic limestone, beneath 2 feet 6 inches of loamy soil. Fifty yards off, towards the footpath to Great Hazeley, a small digging on a level with the bottom of this pit shows the typical pale yellow sands which extend from here, so far as the soil indicates, about half way to Great Hazeley.

Great Hazeley was at one time famous for its stone. Phillips speaks of it as having been quarried from ancient time, and some of Fitton's best sections were obtained here. Now the abandoned quarries, several acres in extent, speak forcibly of the economic changes of this century. The only quarry which had evidently been worked recently was a small one in a field near the church, at the eastern end of the village, where the section is as follows:

SMALL STONE-PIT NEAR THE CHURCH, GREAT HAZELEY.

	ft.	in.
5. Rubbly white limestone with many casts of small shells, passing up into soil	2	6
4. Thin-bedded, crumbly, calcareous and glauconitic sands, about	3	0
3. Black-spotted (not glauconitic) sandy limestone, with casts of *Trigonia*, etc., passing down in about a foot into calcareous sand with shells (*Ostrea*, *Pecten*) in places, which passes locally into hard, slightly glauconitic sandy limestone	4	0
2. Soft, coarser, brownish sand ... ... about	1	3
1. Hard, sandy limestone... ... ... over	1	0

Bed 3 projects as a ledge over 2, which is damp and mossy.

The only other exposure of interest that I have seen in this district owes that interest chiefly to historical reasons. This is one in a field near Peg's Farm, 1 mile S.S.E. from Great Hazeley. Although very small, and now partly overgrown with brambles, it appears to be the one seen by Dr. Fitton, by the officers of the Geological Survey, and by Prof. Blake. It shows about 3 feet of very rubbly limestone full of *Trigonia*-casts.

A N.W.—S.E. line, parallel to the one already mentioned, and about 4 miles distant from it, forms the limit of the Portland beds in this district. A third parallel line, at least

2½ miles farther to the N.E., must be crossed before we see lithological Portland beds again, but then they have an uninterrupted outcrop for over 10 miles.

Main Outcrop, Thame to Bierton.—The first sign of the reappearance of Portland beds, so far as I have seen, is in a field on the north side of the railway and west side of Rycote Lane (which here crosses the railway at right angles), close to the hamlet of North Weston, a mile and a half west of Thame. The brook which crosses the field runs apparently on clay, but, as the ground rises, sand is seen thrown up in the molehills. This is a pale, fine sand, with a little glauconite, totally different from the "Lower Greensand" material that may be seen in the molehills farther west beyond Rycote Pond. I know of no evidence but the molehills in this neighbourhood. The field in question is shown as either Lower Greensand or Gault (the former being stated to be much obscured by drift) on the one-inch geological map, but on the new Index Map a considerable stretch of Portland is shown near here.

The first exposure of importance is at Priestend, the western suburb of Thame, where a pit close to the new Grammar School shows 15 feet of Portland Sand, compacted into sandstone in places, covered by 5 feet of drift, containing flints, flint-pebbles, quartzite-pebbles, and lydite-pebbles. The Portland Sand is dug here for mixing with the Gault Clay at the new brickfields, a third of a mile farther along the Shillingford Road.

The thickness of drift shown in this sand-pit illustrates one of the difficulties of geological mapping in this neighbourhood; it was specially referred to in the memoir accompanying Sheet 13, and is doubtless the explanation of the remarkable difference in the lines drawn on the new Index Map. The drift, however, varies rapidly in thickness, and in many places round Thame there is no difficulty in determining the "solid" rock, which here is most frequently Portland Sand.

As Fitton has remarked, the Portland Sand attains its widest extension around Thame. The cart-road that runs direct from Moreton to Thame is in parts so sandy that one might imagine oneself close to the sea-shore. In the lane leading from near Grove Cottage to the windmill, a deep ditch at the side shows typical Portland Sands, slightly glauconitic. Small exposures may also be seen at Moreton, at the side of the pond near the Bell Inn, and in the roadside towards the eastern end of the village. In Thame itself I saw an exposure in Pound Street, and the rising ground north of the Kingsey Road (which is probably the Barley Hill of Fitton) shows sandy soil.

Throughout the area between Moreton and Thame bounded by the main roads running southwards from the latter, I have seen no evidence of any limestone in the Portland beds, though Fitton mentions its occurrence at Barley Hill. Whether this is to be

explained by Cretaceous overstep or lithological change is difficult to decide, as the relation of the upper part of the Portland beds to the overlying Shotover beds (if such they be) and Gault is obscured by drift.

The Cuttle Brook, which flows past Moreton and Priestend (not the similarly named brook near Kingsey) has cut down through the sands to the underlying clay, a fact not recognised in the one-inch map, but shown on the new Index Map. Near Moreton itself the clay is largely covered by a peaty deposit, but lower down the brook it is visible, and at Priestend two springs, one on each side of the brook, probably mark the base of the sands.

Fitton speaks of Portland Stone as quarried at Cotmore Walls (Colmorewells Farm of the six-inch map), which is nearly half-way between Thame and Towersey. It is probable that a number of stone-pits have been closed in the neighbourhood of Towersey and Kingsey, as I have failed to find any trace of some mentioned in the Survey memoir to Sheet 13. The site of the pits mentioned by Fitton as "near the windmill at Towersey" can, however, easily be identified, although the windmill itself has disappeared. They are about 200 yards south of the Kingsey Road, to the east of the road that joins it from Towersey. Nothing can now be made of them, but in the next field to the south, a small opening has lately been made which shows Portland Limestone with Purbeck beds above. As very little of the former is shown, the section will be described under the Purbeck beds (p. 39).

Portland Limestone is rather feebly exposed at the bridge over the Cuttle Brook on the Kingsey Road, and at another point, a quarter of a mile higher up the brook, as well as at the bridge over the Ford Brook on the road from Kingsey to Haddenham. Around Haddenham itself, there are practically no exposures, though the presence of limestone can be easily recognised in many of the ploughed fields.

The lower sandy beds, though, doubtless, forming most of the lower grounds between Thame and Haddenham, are nowhere well exposed to my knowledge, except in the lane leading down from Scotsgrove to Scotsgrove Mill. Here 12 feet of typical Portland sands are well shown, and near the top there is the lydite-bed, surmounted at once by limestone with "*Ammonites giganteus*," above which there is again sand.

Along the left side of the Thame, between Scotsgrove and Cuddington, the base of the lithological Portland is marked by springs, of which one, the Yolsum Spring, has a distinctly ferruginous taste.

We have now reached the neighbourhood of the Dadbrook Hill section. The interesting field-pit near King's Cross will be more particularly described under the Purbeck beds; here we are

only concerned with the Portland limestone at the base of the section. About 3 or 4 feet of chalky limestone is exposed, and is highly fossiliferous—*Cardium dissimile*, *Pecten lamellosus*, *Trigonia damoniana*, a large *Ostrea*, and "*Ammonites giganteus*" being abundant.

In addition to the trench-exposures down Dadbrook Hill, both sand and stone are less distinctly exposed in the roadway on the north side of the valley, rubbly limestone is seen in the lane on the north side of Dadbrook House grounds, and chalky limestone in the roadway at the top of the hill in Cuddington village.

Continuing eastwards, we soon come to the neighbourhood of Dinton, where Fitton has described the section in a pit which had yielded stone for over 200 years. Now the pit has long been closed and converted into an orchard, but the name of "Stone-pits" is still applied to the farm. The old stone-pit can be seen from the footpath which runs from Westlington across the main road and over the hill to the Cuddington road.

Limestone is exposed in the fields south of Westlington House, in the roadway by Dinton Church, in the farmyard at Upton, and in a field north of the main road near the parish-boundary between Dinton and Stone. At the County Asylum, just beyond that boundary, a boring was made through 20 feet of Portland beds and 500 feet of clays below, but the details known are very meagre.

Just beyond the south end of the Asylum grounds, and a little below the 300 contour, there is a spring which marks the base of the lithological Portland. Beyond this, sloping down to the Ford Brook, there is a stretch of low ground, which is an inlier of Hartwell Clay. The boundary of this inlier can be traced from near Ford north-westwards to Westlington and Dinton, and round by Upton and Stone to Chilborough Hill Farm. It follows the foot of a well-marked surface-feature, and the difference in the soil when one passes from the clay to the sands is readily noticed. It is possible also roughly to draw from surface-indications a boundary-line between "Portland Sand" and "Portland Stone," which may here be a line of more value than elsewhere. From near Wallace Farm (between Dinton and Upton) a long tongue of higher ground runs out south-eastwards. I have not been over this, but have no doubt that it consists of Portland Sand, as mapped by the Survey.

The southern boundary of the inlier is much less definite. From Ford to Chilborough Hill Farm I failed to find any trace of lithological Portland, although an outcrop of it is marked on the new Index Map (though not on the one-inch map), and Fitton especially mentions "about midway between Ford and Moreton's Farm" as one of the points where Portland limestone was to be seen. The area through which the boundary must run is flat grass-land; clay only is exposed in the bed of the two branches of

the Ford Brook, and clayey material in the molehills. The only point where anything appeared to intervene between the Gault and Kimeridge Clays is near Bridgefoot Farm, where I saw pebbly ferruginous sands, probably belonging to the Bishopstone beds.

Returning to the main Portland outcrop, we find the base of the sands marked by the "Egyptian Springs," near Hartwell. The sands are nowhere exposed in anything better than a molehill anywhere between here and Aylesbury, but the limestone has been abundantly quarried, and though many of the pits described by Fitton and Morris are now filled up and grassed over, a good many small exposures may still be seen. Such are the old pit 150 yards south of Stone Church, where very chalky limestone with abundant fossils of the usual species is seen, and a small pit at Upper Hartwell, now made into a garden.

The famous Bugle Pit is the only large exposure near here, and has been so often described in the PROCEEDINGS and elsewhere that I need not refer again to it. The extent to which the Portland beds have been worked hereabouts is indicated by the abundance of gigantic Ammonites used for wall decoration.

Small exposures of limestone occur near Sedrup (Southwarpe of the old maps), whence Fitton obtained several fossils; but the numerous pits that have been described at Bishopstone seem now to be entirely closed and overgrown. The famous Locke's Pit, where the Hartwell Clay is dug and the pebble-bed rather poorly exposed, is about a mile and a half due north of Bishopstone. The pebble-beds can be traced in the fields to the south of this pit. Along the footpath from Bishopstone to Walton, limestone is exposed in a small pit, about half a mile north-west of Stoke Farm, which will be described under the Purbeck. Farther along, limestone with *Trigonia*-casts is exposed in the side of the brook which is crossed just before the path joins the Stoke Mandeville Road. The rubbly limestone with the sands above and below it is well exposed in the cuttings of the Metropolitan Railway between Walton and the Aylesbury Joint Station.

Aylesbury itself is built on an outlier of Portland, detached from the main outcrop by stream-erosion. The beds have frequently been exposed in drainage operations and the like, but I know of no good permanent exposure.

Leaving Aylesbury by the Leighton Road, one soon crosses the narrow separation between the two outliers, the presence of the Hartwell Clay being marked by a brickfield, from which the characteristic fossils can be obtained in abundance. Above 10 feet of the clay the lydite-bed is well shown.

Less than half-a-mile farther on, on Bierton Hill, opposite the Manor House, drainage works were in operation last September, and a depth of perhaps 15 feet of Portland Sand was exposed, with water at the bottom (indicating, in that very dry season, a very near approach to the clay). As I only saw these exposures

for a few minutes at dusk, I cannot say more, but the great thickness of sand was striking. There are several old stone-pits near Dunsham Farm, but only one now in work; this shows a succession very like that of Hartwell, and the beds dip 10° to the east—a dip which must be cut off by the fault shown on the published map.

At the brickfield in Bierton village Hartwell Clay, with *Astarte mysis*, *Mytilus autissiodorensis*, *Cardium striatulum*, and *Exogyra nana*, is seen to a depth of 15 feet or more, and, overlying it, the lydite-bed of the Upper Portlandian, here an impure, brown, sandy, and pebbly limestone, with casts of large *Trigoniæ*.

This is the most easterly exposure that I have visited in the district, but exposures have been recorded at Warren Farm, south of Stewkley and near Cublington, in the drift-covered district towards the north-eastern watershed.

OUTLIERS: LONG CRENDON TO CONEY HILL.—This row of outliers has been separated from the main outcrop by the cutting of the Thame valley. Such a row of outliers is an unusual feature in areas of gently-dipping beds with a well-adjusted drainage system. Outliers beyond the main escarpment are usually separated from it by the cutting back of head-waters, and mark subsidiary transverse water-partings, or "sub-divides." An explanation of the peculiar features of the Thame valley will be suggested later on (Part VI).

The best sections on this line of outliers are at the extreme ends. Those at Long Crendon I have already described. At Coney Hill, or, more correctly, Waddesdon Hill, the following section is now to be seen, at the "Limekiln" marked on the six-inch map, a quarter-mile west of Coneyhill Farm, and near the lodge at the northern entrance to Eythrope Park:

SECTION AT LIMEKILN, ¼-MILE WEST OF CONEYHILL FARM.

		ft.	in.
11.	Soil, with small limestone fragments and lydite pebbles ...	1	0
10.	Drift, with abundant limestone fragments	1	0
9.	Calcareous sand, finely laminated	1	3
8.	Sandy marl	0	8
7.	Friable laminated limestone	1	2
6.	Massive limestone	1	0
5.	Friable laminated limestone	1	0
4.	Thin-bedded limestone ... ... about passing into	1	0
3.	Massive creamy and chalky limestone (*Trigonia*, *Cardium*, *Ostrea*, *Natica*, etc.)	2	0
2.	Thin-bedded limestone and marl	1	6
1.	Massive creamy limestone	2	10

The uppermost beds here are Purbeck, and the line between Purbeck and Portland should probably be drawn at the base of Bed 5, which yielded marine Ostracoda, found elsewhere in

the Purbeck beds of the district. If this is the section seen by Prof. Blake nearly twenty years ago, it must have been worked to a much deeper level then, since it is from Coney Hill that he obtained many of the "rubbly limestone" fossils.

The lower rubbly limestone and the pale sands below it are exposed in the roadside close by the quarry, and the base of the sands can be seen at the pond below Coneyhill Farm.

In the intervening area between Long Crendon and Coney Hill I have not seen any sections of importance.

Two further outliers—those of Ashendon and Lodge Hill (capped by Waddesdon Manor)—run parallel to the line just referred to, being separated from it in more normal fashion by a secondary longitudinal stream. I have not visited either of these, but their appearance from a distance clearly indicates their nature. The south-westerly continuation of this line of outliers is represented by the north-westerly extension of that of Long Crendon to Chilton.

OUTLIERS: BRILL AND MUSWELL HILLS.—My only visit to Brill and Muswell Hill was a brief one, and I have nothing to add to the accounts that have previously appeared. I may point out, however, that in the presence of only 3 feet of mealy sand between the lydite-bed and the fossiliferous Hartwell Clay, this district shows characters intermediate between Long Crendon and Dadbrook Hill.

It seems possible that these outliers owe their preservation to being on a gentle synclinal axis at right angles to the general strike—an axis which may find its continuation in the break of the line of Cornbrash inliers between Merton and Blackthorn Hill. The other breaks in that anticlinal line also seem to be continued as synclinals into our district. But where the dip averages less than half a degree, and horizons are not certainly marked by lithological lines, the recognition of such gentle folds is difficult.*

OUTLIERS: QUAINTON HILL AND OVING.—The base of the lithological Portland rises through 200 feet in the six miles between Aylesbury and Quainton Hill. This indicates a dip which, though double that estimated at Dadbrook Hill, is considerably less than half a degree. There are several pits and small exposures on Quainton Hill, but not enough to enable a complete section to be compiled. As elsewhere, however, the lower part of the Portland beds is mainly sand, the upper calcareous.

On the eastern side of the northward spur, called "Conduit Hill," about 30 feet above a spring, which marks the base of the sands, a small opening showed a little rubbly, fossiliferous limestone with *Cytherea rugosa* and *Pleuromya tellina*, overlying 3 feet

* Some general suggestions as to post-Jurassic folds, based on a comparison of this district with the distribution of Jurassic rocks under the London area, were made in the paper as originally read. They are withdrawn with a view to fuller treatment later.

of calcareous sand with large concretions, like those of Littleworth, near Wheatley.

A furlong south-west from the summit of Quainton Hill a larger opening showed the following section:

SECTION A FURLONG SOUTH-EAST OF THE TOP OF QUAINTON HILL.

		ft.	in.
SHOTOVER BEDS (?)	6. Ferruginous sands with ironstone; clay at base in places	8	0
PORTLAND BEDS.	5. Brashy limestone (*Trigonia*)	2	6
	4. Creamy limestone (*Trigonia* casts, *Cardium dissimile*, *Ostrea* etc)	6	0
	3. Fine buff sands, slightly glauconitic, not calcareous	6	0
	2. Sandy and shelly limestone	2	0
	1. Calcareous sands.		

This seems to show what Fitton calls a "gull," *i.e.*, a pipe in the Portland beds, into which tbe overlying clay and ferruginous sands have been let down gently. Fitton, it is true, asserts that the gull must have been excavated before the deposition of the matter that now fills it; but in the case he mentions (at Great Hazeley), as well as in the present one, there are among the beds filling the gull clay-beds of uniform thickness. It would be impossible for such a bed to be laid down on a slope of from 45° to nearly 90° without being much thicker at the bottom, therefore we can only suppose it to have been level originally, and let down long afterwards.

Several smaller sections near the top of the hill show Portland limestone, but with overlying Purbeck beds; they will therefore be considered later.

Eastwards it is easy to see that the Portland beds extend some way beyond the limits laid down on the published map. The proper shape of the outlier is roughly indicated on the key map, Fig. 1. It includes Woad Hill and Denham Hill. On the latter, a little way above Denham Hill Farm, I found a very obscure section, seemingly with a fault running through it, the beds differing totally on the two sides, and being greatly obscured by talus-slope. There are marly and clayey beds suggestive of Purbeck, and more massive limestone, but nothing very satisfactory: in the former I found a single marine ostracod (*Bythocypris winwoodiana*, see Mr. Chapman's notes, p. 58).

Close by, in the next field, to the west, an indentation of the 500 contour line marks an old quarry where limestone may be seen. Lower down the hillside a couple of springs mark the base of the lithological Portland. In the case of the more westerly one there is a fair exposure of calcareous sands (in which I noticed a *Trigonia*-cast) over the clay, and from here to the lowest point where limestone can be seen is quite 30 feet vertically, all between seeming to be sand. This agrees with observations

at the north end of the hill, and I think we may safely regard the lowest 30 feet of the lithological Portland as entirely sand, while the remainder is mainly, but not entirely, limestone. The thickness of the latter I can only estimate by considerations of level, and those give it about 45 feet, making 75 feet in all. I have not seen any sign of the lydite bed on Quainton Hill, but that may be because at the time I visited it I was not impressed by the importance of the lydite bed, and did not look for it.

The outlier around Oving was visited by the Association in 1897, and the exposures there are chiefly interesting for the Purbeck beds. At two points there are sections showing fossiliferous Portland limestone overlying sand—one (visited by the Association in 1897) is on the road to North Marston, 100 yards before it crosses the 500 contour. The other is by Creslow Church. Here 5 feet of limestone are seen, with a marly band in the middle, and over 3 feet of the usual pale sand beneath. The limestone here is very fossiliferous — "*Amm. giganteus*," *Trigonia*, *Cardium dissimile*, *Ostrea expansa*, *Natica*, etc., being present, and a small *Ostrea* occurs in the sand.

Limestone with sand underneath is seen in Weir Lane, north of Bolbec Castle, Whitchurch, though the Portland sand was not mapped at this point by the Survey. Limestone also forms the actual roadway in part of Whitchurch village, as Prof. Blake has noted.

III.—PURBECK BEDS.

The marine Portland beds are followed conformably by a series of marls, clays, and thin-bedded limestones containing estuarine and fresh-water fossils—the Purbeck beds of the district. In adopting this name for them, I express no opinion as to their equivalence with the typical Purbeck beds of the south coast. I use the name as a facies-name, not a time-name. Owing to the pre-Cretaceous (or early Cretaceous) denudation of the Jurassic rocks, these uppermost strata do not possess a continuous outcrop but occur in scattered patches, irregularly overstepped by the Cretaceous beds above. Being nowhere of great thickness, and having no lithological unity, the recognition of their presence from surface-characters is extremely difficult; though in a section they are readily distinguished from the more massive limestones beneath. It is not surprising, therefore, that no attempt was made to map them on Sheet 13 of the one-inch map, although their presence was recognised, and that on Sheets 45 and 46 only seven patches of Purbeck are mapped, although at least a dozen seem to have been known to Fitton. Altogether I find previous evidence of sixteen, and to these I can myself add two, making a total of eighteen, of which some may be only parts of a single patch. Of these patches

some are outliers, one is mapped as an inlier, while others, being of the nature of discontinuous outcrops, might be spoken of as "in-and-out-liers," or "tween-liers."

1. and 2. COMBE WOOD AND GARSINGTON.—Purbeck beds are recorded from these two places by Fitton. I could find no exposures

3. LONG CRENDON.—Here also they were noted by Fitton. I have given the section now exposed at page 22. For fossils see table on page 43.

4. BRILL.—Purbeck beds have been noted here by Brodie and Phillips.

5. TOWERSEY.—Purbeck beds have not yet been recorded from here. In a pit close to the site of the windmill (now destroyed), half a mile north of the village, the following section may be seen:

FIELD-PIT ON E. SIDE OF ROAD FROM TOWERSEY TO KINGSEY, NEARLY OPPOSITE SITE OF WINDMILL.*

		ft.	in.
PURBECK.	12. Soil	1	0
	11. Band of nodular calcareous chert	0	2
	10. Thin-bedded limestone	0	4
	9. Marl, with nodules at base	0	8
	8. Thin-bedded limestone	0	6
	7. Marl with *Paludina*	0	9
	6. Thin-bedded limestone	1	3
	5. Ferruginous sand, slightly clayey	0	3
	4. Marl	0	8
PORTLAND.	3. More massive limestone	1	0
	2. Thin-bedded limestone	0	11
	1. More massive limestone (*Cardium dissimile*)	1	0

Bed 5 is conspicuous on the face, because of the moss that grows along it. Bed 7 is full of young *Paludinæ* of indeterminable species, but two of the larger ones appeared to be *P. elongata* and *P. sussexiensis*. I also found a single tooth of a pycnodont fish (*Cœlodus*?) and some freshwater Ostracods (see p. 43).

The Purbeck beds cannot extend far around these pits, as Fitton does not mention their occurrence in the old pits a furlong to the north, and I could not find any clear evidence of them between the Portland and Gault along the Cuttle Brook, a quarter-mile to the west.

6. HADDENHAM.—A small outlier, partly overstepped by "Lower Greensand," has been mapped a little west of the village. There was probably a pit here at one time, for Fitton specially mentions this as a locality where Portland beds may be seen rising from beneath the higher strata. Now, however, I have failed to find any evidence of the presence of Purbeck here.

* Photographs of this section and the next one (King's Cross) have been given by Mr. J. H. Pledge to the British Association collection.

7. KING'S CROSS, north of Haddenham.—At the point where this stone-pit (already referred to in the Dadbrook Hill section, pp. 22, 33) is opened, the Geological Survey has mapped Gault resting directly on Portland Stone. It is probable that the black clay and marl of the Purbeck (Beds 6 to 9 of the section below) were mistaken for Gault—not a surprising mistake in the absence of any clear section. The fossils given below are amply sufficient to prove the Purbeck age of the beds.

FIELD-PIT, N. SIDE OF MAIN ROAD, 120 YARDS WEST OF KING'S CROSS, HADDENHAM (1898).

	ft.	in.
10. Soil (and Drift ?)	0	6
9. Yellowish-white marl	1	0
8. Brownish clay, slightly calcareous...	2	0
7. Tough black clay, scarcely calcareous at all	2	0
6. Brownish, more laminated clay, sandy and not calcareous, the lowest portion weathering with a white efflorescence	1	0
5 Reddish sand with some lydite-pebbles, and thin iridescent shell fragments; ironstone at base in places ... about	0	7
4. Dark marl with pebbles ... ... 7 in. to	1	2
3. Lighter marl, the lower part giving an odour of petroleum when hammered ... ... about	1	6
2. Marly limestone	0	4½
1. Massive chalky limestone, with *Cardium dissimile*, *Trigonia damoniana*, "*Amm. giganteus*," *Pecten*, *Ostrea*, etc.	3	6

There are slight traces of contemporaneous erosion between 4 and 5. It is even possible that this may indicate a break of some importance, for the ostracods found in Bed 7 indicate a much higher horizon than those in Beds 3 and 4. From Bed 7 I obtained fine specimens of *Cypridea punctata* (Forbes), undeterminable fragments of Gasteropods and Lamellibranchs, and carpogonia of *Chara*. Of the *Cypridea punctata*, Mr. Chapman writes to me that it is characteristic of the Upper and Middle Purbeck, but very rare in the Lower. "The fine and numerous specimens are, I should say, rather indicative of the Upper series, but that can only be said with some reserve." In Bed 3 there is a curious mixture of fresh-water and marine ostracods and foraminifera. The former are given in the table on p. 43, and are Lower Purbeck forms. Among the latter Mr. Chapman identifies *Cristellaria cultrata* (Montfort), from the middle part of the bed, and *C. varians*, Bornemann, from the top, and states that "in addition to these there are several interesting foraminifera from the same bed which will require further study." The only other identifiable fossil was a *Serpula*, but fragments of oysters occur at the base.

Since this paper was read I have been in correspondence with Mr. Jukes-Browne, of the Geological Survey, who re-examined this district officially in 1887, and saw the section at

this pit. As the section then exposed differs to some extent from the present one, I am glad to be able to give Mr. Jukes-Browne's account of it, which he has kindly allowed me to do, with the permission of the Director-General of the Geological Survey.

STONE-PIT ¾ MILE S. OF CUDDINGTON.

		ft.
	Soil (heavy)	1½
6.	Marly rubble with bits of stone passing down into marly clay	1 to 2
5	Light-grey calcareous clay with a lenticular bed of limestone near entrance to pit, above which is a continuous band of dark grey clay	1 to 2
4.	Grey soapy clay, passing into black clay	3
3.	Dark brownish shaly clay, with brown (ferruginous) and yellow (sulphur) stains	1½
2.	Brown sand full of comminuted shells in the upper part, with some pebbles of limestone	1½ to 2
1.	Hard calcareous laminated sandy loam with derived shells at base	1 to 1½
	Hard white Portland rock	4
	Total about	16

[No. 2 thickens at the expense of No. 1.]

A comparison of the two sections shows several interesting points. It is safe to assume that the present face is farther east than the 1887 one. Beds 3 to 5 of the latter correspond exactly to Beds 6 to 9 of the former, the differences being much slighter than the verbal differences in the description might suggest; the lenticular bed of limestone, however, has now thinned out altogether. Bed 2 of Mr. Jukes-Browne is my Bed 5, and its rapid westwardly increase in thickness is in full accord with the evidences of contemporaneous erosion at its base; evidently we have here a stream-channel cut down in the estuarine or lagoon-deposits below, in which latter, throughout the district, sandy beds are very rare. Bed 1 of Mr. Jukes-Browne is probably the lower part of my 3 and 2, having changed in lithological character.

It is very difficult to say how far these Purbeck beds extend around this pit, as surface-indications are not at all trustworthy in distinguishing Purbeck from Portland, unless the former are very clayey. The only other point where I have actually found Purbeck marl in place is in the roadside ditch by Budnall Farm; but the clayey soil of the fields on the opposite side of the road indicates its presence there. The boundaries drawn on the map (p. 54) must, therefore, be taken as approximate only; they are based largely on considerations of slope and dip, and only to a small extent on actual tracing over the ground.

8 AND 9. FROM CUDDINGTON TO BEYOND DINTON two parallel strips of Purbeck, separated only by the overstepping Cretaceous beds, have been mapped by the Survey. These are

doubtless continuous with one another, and with the previous patch, underneath the Cretaceous. I know of no good exposures along this line, but it includes the Dinton stone-pits described by Fitton (see *ante*, p. 33).

10. STONE.—This large outlier has the Bugle pit as its only satisfactory exposure. The most notable feature here is the fine-grained and well-jointed bed of "Pendle" at the base. The working-back of the quarry-face has revealed the rapid lateral changes which the Purbecks undergo. Thus the face worked at the present time (November, 1898) shows six feet of unbroken marl, separated from the pendle by seven inches of crumbly limestone, and five inches of slaty-blue clay. Tracing the beds some yards to the south, in an old face we find the marl broken up by three bands of rubbly limestone.

11 AND 12. BISHOPSTONE AREA.—A large area is mapped by the Survey as Purbeck between Stone and Bishopstone, with a very small inlier in Bishopstone village itself. A number of pits are referred to by Fitton, Morris, and Rupert Jones as within this area, but, though I have seen several overgrown and partially-levelled pits, I have not found one still in use, or even recently abandoned, and very few are marked on the six-inch map now nearly twenty years old. Purbeck Marl may be seen occasionally in ditches.

13. AYLESBURY.—A small patch of Purbeck that can hardly cover ten acres is shown on the Survey map about half-way between Stoke Farm and Locke's brickfield. A small pit is open in this patch beside the Walton-Bishopstone footpath, and within the parish of Aylesbury, and though not now in use shows the following section very clearly :

SECTION IN FIELD, ¾-MILE FROM WALTON ALONG BISHOPSTONE FOOTPATH.

		ft.	in.
PURBECK.	8. Soil (and drift ?) ... ... about	2	0
	7. Thin-bedded limestone	1	0
	6. Light-coloured marly limestone	0	6
	5. Dark marly limestone	0	8
	4. Crumbly, very thin-bedded limestone with ostracods	0	7
PORTLAND.	3. Chalky limestone, rather thin-bedded ...	4	0
	2. Marl, passing up into clay	0	3
	1. Chalky limestone	3	0

This section is chiefly of interest from the occurrence in bed 4 of the same mixture of freshwater and marine ostracods and foraminifera as in Bed 3 of the King's Cross section. Of the latter Mr. Chapman identifies *Cristellaria* sp. and *Patellina* sp. The former are given in the table opposite.

14. CONEY HILL.—The section has been given on page 35. For a list of ostracods from bed 5 see opposite.

TABLE OF LOWER PURBECK OSTRACODA FROM THE THAME VALLEY.

		Pit by Lower Windmill, Long Crendon. (p. 22).	Pit near site of Windmill, N. of Towersey. (p. 39). Bed 7.	Pit near King's Cross, Haddenham. (p. 40). Bed 3.	Bed 4.	Pit ¾ mile from Walton (Aylesbury) along path to Bishopstone. (p. 42) Bed 4.	Coney Hill (p. 35) Bed 5.
FRESHWATER.	Candona ansata, Jones	× 2	×	× b m	—	×	—
	bononiensis, Jones ...	—	×	× m	×	—	—
	Cypris purbeckensis, Forbes ...	× 2, 3	×	—	×	—	—
ESTUARINE.	Metacypris sp.	—	—	×	—	—	—
MARINE.	Cythere drupacea, Jones ...	—	—	× b m t	—	×	×
	retirugata, Jones ...	—	—	× b m t	—	×	×
	„ *var.* rugulata, J.	—	—	× b m t	—	×	×
	„ *var.* textilis, J.	—	—	× b m t	×	×	×
	transiens, Jones ...	—	—	× b t	—	—	—
	sp.	—	—	×	—	—	—
	Cytheridea ? subeminula, J & S.	—	—	—	—	—	×
	Macrocypris horatiana, J. & S.	—	—	× b	—	×	—
	[See Mr. Chapman's notes, p. 58.]	2 and 3 refer to beds p. 22.		b = bottom m = middle t = top			

Middle Purbeck ostracods were only found at King's Cross (see p. 40).

15. Quainton Hill.—The existence of Purbeck beds under the "Lower Greensand" was noted by Fitton, but they were evidently too uncertain to be mapped. The section previously given (p. 37) shows that they are locally wanting. The best exposure I have seen of them was in a small pit by the eastern boundary of the field which includes the summit of the hill. An opening is indicated here on the six-inch map, but this has been levelled over, and the new one is a few yards farther south. It was evidently worked for the Portland limestone, of which many blocks were stacked up close by, but, as is usual with small pits, the bottom part had been filled in.

Section 160 Yards East of the Summit of Quainton Hill.

		ft.	in.
	5. Soil, full of "Lower Greensand" material, the lower 8 inches, perhaps, being "Lower Greensand" *in situ*	1	6
Purbeck.	4. White marl, passing down into (3) ...	1	0
	3. Finely laminated limestone	0	1
	2. Hard limestone with shells and ostracods, the latter specially abundant towards the top	0	4
Portland.	1. Soft marly limestone with *Trigonia*-casts, *Pecten*, etc.	1	1

Bed 4 varies much in thickness, so that if "Lower Greensand" is really *in situ* above it, the unconformity between them is strongly marked.

16. Oving.—A large outlier of Purbeck is mapped here, and is well exposed in a large number of small pits that have been worked for Portland Stone on the flat top of the hill. They show considerable variation in the lithological character of the beds, but it does not seem necessary to give the details of them in full. This outlier was visited by the Association in September, 1897, and some account of what was then seen appeared in the report of that excursion (*Proc. Geol. Assoc.*, vol. xv., p. 207). In the section given on p. 207, I should now have no hesitation in carrying the Purbeck down to Bed 2, inclusive; while I am very doubtful if the "Lower Greensand" marked there is really *in situ*: more probably it is only sandy soil.

17 and 18.—Weedon; and Warren Farm, near Stewkley.—I have not visited these two outliers, whence Purbeck fossils were recorded by Fitton, but where the outcrops were evidently too narrow to be mapped by the Survey.

IV.—THE "LOWER GREENSAND."

Under this name the Geological Survey has mapped within the district a discontinuous series of patches consisting mainly of ferruginous sands, with frequent beds of ironstone, pebbles, and clay resting on the Purbeck or the Portland beds, usually with

marked unconformity, and in places covered by Gault. Though mostly unfossiliferous, they have yielded fossils in at least five places in our district—marine at two, freshwater at three. Since it is by no means certain that these numerous disconnected patches, about thirty in number, are all of the same age, it seems very desirable to introduce local names for the description of the fossiliferous beds and those stratigraphically connected with them, and to leave the vague term "Lower Greensand" for those cases which cannot with certainty be otherwise defined. I shall, therefore, in this paper speak of them under the following names:

(1) Toot Baldon Beds.—These are the beds extending from near Chislehampton to the Thames at Clifton Hampden and Culham. In them marine fossils of Aptian age have been found.

(2) Shotover Beds or Shotover Ironsands.—This name has been very generally used as a descriptive term. Prof. Blake in 1893 proposed that the term "Shotover Sands" should be used for (apparently) all the "Lower Greensand" of this district. As Prof. Blake had himself used the same term in 1880 for the *Portlandian* sands of Shotover Hill, I think a revival of the old term of "Ironsands" used by Fitton is more satisfactory. I propose that the term be restricted to the beds containing freshwater fossils, or stratigraphically linked with those that contain them.

An important stratigraphical distinction of these beds from the next lies in the two facts that the Shotover beds rarely or never rest directly on Kimeridge Clay (the supposed case at Wheatley being due to slipping) and that they rarely approach near the Gault.

(3) Bishopstone Beds.—I propose this name for the beds developed around Bishopstone, Stone, and Haddenham Low which have yielded marine fossils, though none that definitely fix the age of the beds. The village of Stone has the first claim to give its name to these beds; but as "Stone" has a lithological as well as a geographical meaning, its use might lead to misunderstanding.

(4) Woburn Sands.—I shall use this name in referring to the continuous outcrop of sandy beds with Aptian fossils that starts near Leighton Buzzard and continues north-eastwards towards Sandy and Cambridge. These beds are entirely outside our district, but it will be necessary to refer to them for comparison.

(1) Toot Baldon Beds.

These are, at Toot Baldon itself, fine clayey sands, probably about 20 or 30 feet in thickness. Farther west, towards Nineveh Farm, the clayey character seems to disappear. They are seen again at the little cliff at Clifton Hampden, but here they are far

coarser, forming a gravel of small pebbles, rarely over ¼ inch in length. These pebbles are mainly quartz, but some are of ironstone, and others again are of light-coloured argillite, very perfectly cleaved, so that they break between the fingers along planes almost as perfect as those of a calcite-crystal. This material I have seen nowhere else in the district, but I have found similar pebbles in the Faringdon sponge-gravels. Coarse gravels are again seen just north of the brickyard at Culham, but in the brickyard itself only a few inches of pebbly, glauconitic stone intervene between the Gault and the Kimeridge Clay.

At Toot Baldon itself, in such roadside exposures as could be seen, I hunted for fossils unsuccessfully. There are two previous records of fossils from here. Prof. Hull and Mr. Etheridge found *Ammonites* (*Hoplites*) *deshayesii* and *Terebratula sella*, convincing proofs of Aptian age. On the other hand, Prof. Phillips, in 1860, found, towards the base of the sands, *Mya*, *Pecten*, *Cardium*, *Trochus*, and "an Ammonite of the group of *A. polyplocus*, *A. triplicatus*, and *A. giganteus*," *i.e.*, one of the Planulati of Von Buch or the modern genus *Perisphinctes*. This last fossil is much more suggestive of Upper Jurassic, but as the genus does extend into the Lower Cretaceous, it can hardly weigh against the evidence of the other two species. Still we must not overlook the possibility that here, scarcely more than a mile from Garsington, there may be a trace of the lower sandy beds of the Portlandian beneath the Aptian sands.

(2) Shotover Ironsands.

These famous beds at Shotover itself have been a source of constant discussion, and have been referred variously to the Purbeck, Wealden, and Lower Greensand.

Under the heading, "Shotover Ironsands," I include not only the beds on Shotover Hill, but also those extending from near Wheatley to Garsington, and those at Brill—in all of which freshwater fossils have been obtained. To these may probably be added the beds on Quainton Hill, from which Fitton obtained impressions of *Cyclas* and *Paludina*. If unfossiliferous beds may be allowed a place, I would add those of Long Crendon and Thame, as lithologically more like those of Brill and Shotover than those of Stone, but I know the weakness of such evidence, and only adopt it temporarily in the absence of better.

Shotover Hill Range.—Here the beds were estimated by Phillips as 80 feet thick. They include sands (both white and reddish), ironstone, and clay (white and red). At Shotover itself they rest on sandy Portlandian beds without any intervening limestone, so that their exact lower limit is not easy to fix.

Between Wheatley and Garsington I could find no satisfactory

exposures, except a small sand-pit just by the 400 feet contour, a quarter-mile due south of Littleworth, where 5 feet or so of white and grey sand, false bedded and variously iron-stained is surmounted by a few inches of white clay, and this again by 3 feet of ironsand-slip. Many specimens have, in the past, been obtained from Combe Wood, a mile south of Wheatley; but I could find no quarry there. Judging from the soil of ploughed fields, the beds are mainly coarse ferruginous sands, passing into ironstone. North of Garsington, in the hollow lane leading down to Kiln Farm, these sands are seen to overlie a white clay, under which are again ferruginous sands of no great thickness (see Plate II). It is probably this clay that throws out the springs all round the outlier, the sand above holding an abundance of water even in time of drought, as I found with considerable pleasure during the hottest and driest part of last summer, when these springs continued to flow plentifully though many of those at the base of the Portland were dried up.

All over this outlier the base of the Shotover beds seems to vary greatly and irregularly in level, whereas the Portland beds below appear to have a very regular and gentle dip towards the south-west. Granting that coarse freshwater sands may well have been laid down originally on an uneven surface, it is probable that most of this irregularity is due to subterranean erosions of the top beds of the Portland and Purbeck as shown by Fitton's "gulls" at Great Hazeley (*ante*, p. 37). The exact boundary-line of the Shotover beds is also difficult to trace in many places, by reason of the extensive slipping that has taken place down the hill-sides. As I have previously shown (pp. 28, 29) this slipping has been taken for overstep between Wheatley and Littleworth. It is well shown in the lane-section north of Garsington, and I suspect its existence at other points. It is not unlikely that the subterranean erosion of the underlying beds, where it has given the Shotover beds a dip towards the hill-side, has been the ultimate cause of the slips. I need hardly point out that the discrimination between slip, irregularity due to subterranean erosion, and original overstep (which also exists almost certainly) is a troublesome matter along a line where exposures are few, and I have not attempted it in detail.

MUSWELL HILL, BRILL, LONG CRENDON, AND THAME.—At Brill there are abundant exposures of the Shotover beds at the top of the hill, but there seems to be much slipping, and in the short visit I paid I did not determine any regular sequence, though I estimated the beds at 50 feet in thickness. They are a very variable set of sandy and clayey beds—the sands white, pale violet, and reddish; the clays blue, violet-black, and dark brown.

On Muswell Hill the sands seem to be mainly ferruginous, but I did not notice any good exposure.

At Long Crendon the beds are plainly seen lying between the Gault and the Purbeck, and are only 4 feet thick. One section has already been noted (p. 22 and Plate II). Another, 50 yards or so farther north, showed a rapidly varying set of sands and clays.

In the brickfield, a quarter of a mile south of Thame station, there are several small openings, one showing fossiliferous Gault; another purplish-grey and yellow sands, with ironstone above and below; and a third, soft white clay. This seems to be the descending succession, but I could make out no actual junction.

The characteristic features of these beds from Brill to Thame are the abundance of clay and fine clayey sands, and the rarity of coarse sand and pebbles.

I have not been able to trace the beds east and west of Thame owing to the abundance of drift, and the absence of any limestone between them and the Portland sands. In the section near Towersey (p. 39) nothing was seen above the Purbeck, although according to the Survey map Lower Greensand, if not Gault as well, should here be present.

QUAINTON AND OVING.—The exposures I have seen on Quainton Hill all show ferruginous sands with pebbles, and might just as well be correlated, on lithological grounds, with the Bishopstone beds as with the Shotover beds. But as Fitton obtained casts of freshwater shells from them, I include them here. They appear to rest on Purbeck or Portland beds with a strong unconformity; but in one pit at least (p. 37) this is due to subterranean erosion of the underlying beds.

At Oving, the only section I know of was visited by the Association in 1897, and is described in the report of that visit in these PROCEEDINGS.

Bishopstone Beds.

BISHOPSTONE TO HADDENHAM.—These extend from just north of Haddenham in a broken curve, along the line of high ground followed by the main road from Thame to Aylesbury, and down to Bishopstone, where they appear to pass under the Gault. In addition there are a number of small outliers mapped by the Survey.

The general sequence of these beds is shown in Plate II (Stone and Hartwell section). The best exposure is that at the Windmill, Stone. During the last three or four years this has been actively worked, and its appearance has varied to some extent. It was at its best about the middle of May, 1898, when it showed a very pretty fault on the two end faces, running parallel with the main face, *i.e.*, almost due east and west, with a downthrow of a couple of feet or so to the north. In September my friend Mr. Pledge took a photograph of the section, a copy of which is now in the British Association collection. The details of this section have

varied somewhat from time to time. The following measurements were taken in March, 1897 :

WINDMILL SAND-PIT, STONE.

	ft.	in.
6. Sandy clay	3	4
5. Sand and ironstone	0	9
4. Sandy clay	0	3
3. Sand and ironstone	1	5
2. False-bedded white and grey sand with pebbles, from 5ft. 6 in. to	7	9
1. True-bedded firm grey sand	3	6

This section shows evidence of the following series of events:

(1) Deposition of the lowest sand in relatively still water.

(2) Removal of part of it by currents and deposition of pebbly sand at various angles.

(3) Truncation of the false-bedded sands by a horizontal plane, and deposition of sandy clay, etc., in comparatively still water.

A noteworthy feature of this pit is the absence of ferruginous sands, which are seen in other pits close by. The three following sections will illustrate the variations in the character of these beds.

MR. CASTLE'S PIT, ¼ MILE ALONG EYTHROPE ROAD, STONE.

	ft.	in.
6. Sandy soil 5. Bluish-white plastic clay	5	0
4. Bright orange sand	1	0
3. Whitish sand	0	6
2. Black loam	2	0
1. White sand, with a few seams of black loam ; few pebbles, some false-bedding	12	0

MR. CASTLE'S PIT, SOUTH OF STONE VILLAS, STONE.

6. Soil and drift	2	6
5. Clayey sand	0	4
4. Clay	0	9
3. False-bedded sand with pebbles and ironstone	6	3
2. Lenticular band of Fuller's earth ... ... up to	0	9
1. False-bedded sand, etc.	10	0

OLD SAND-PIT, NORTH SIDE OF MAIN ROAD, EAST OF STONE FARM, STONE.

	ft.	in.
5. Soil	1	6
4. Clay	0	6
3. Clayey sand	0	8
2. Clay	1	0
1. Light-coloured sand	9	0

In this last pit, the beds given are capped, a little farther east, in an old, obscure face, by a band of hard ferruginous conglomerate of small pebbles. This conglomerate does not seem to extend far.

In none of these sections is the base of the sand exposed,

and in none could I find any trace of fossils. Morris recorded *Endogenites erosa* from the base of the sands in Stone village, but the only marine fossils which he obtained were from his "Red Sand Pit," the site of which I have identified as in the field which lies between Peveral Court grounds and Calley Farm. This site is marked by a depression of the ground, evidently artificial, and it agrees with the order in which Morris described the pits. When I first visited this field, in March, 1897, it was ploughed over, and the pebbly ferruginous sands were well seen; but on returning there, in 1898, in the hope of finding fossils, I was disappointed to find the field in grass. This pit is not on the same outlier as those above described, but on a smaller one, south of the main road.

The fossils from this pit are preserved at University College, and through the kindness of Prof. Bonney I have been able to examine them, and they were exhibited at the meeting on December 2nd, 1898, when this paper was read. They include a very good piece of coniferous wood, and casts in coarse sandstone of a small coral, *Pecten*, *Spondylus*, and other marine shells, including one identified as *Exogyra sinuata*. If this identification is correct,* it fixes the age of these beds pretty closely, since that species does not occur below the Atherfield clay and its equivalents (Rhodanian or Urgonian), though it ranges to the top of the Lower Greensand (base of Albian).

Besides these indigenous fossils, Morris describes the occurrence of derived blocks of compact brown sandstone, with casts of *Unio*, *Cyrena*, *Paludina*, and traces of plants. Only one fragment of such sandstone is preserved in the collection that I saw at University College, and the casts in that do not seem enough to establish the freshwater origin of the sandstone. I may mention that I found one block of coarser sandstone full of casts of a gasteropod (*Paludina* ?) at Castle's pit, near Stone Villas, but unfortunately it was in the soil, not *in situ*, and therefore proves nothing.

In the "Explanation of Horizontal Section Sheet 140," casts of marine fossils in "gritty and ferruginous beds between Hartwell and Bishopstone" are recorded. These may be from Morris's pit, or from some other one. I know of no pit open at present, or even recently abandoned, between Hartwell and Bishopstone.

I may say here that I feel very doubtful as to the correctness of the mapping of the little outlier in which this pit occurs. The topography of the old one-inch map is quite clear and fairly correct at this point, and the outlier is shown as about 370 yards broad, extending south-westwards to within about 200 yards of the Stone-Bishopstone road, and north-eastwards to within about 130 yards

* I am not sufficient of a palæontologist to venture to express an opinion on the specific identity of a cast; but at the meeting Prof. J. F. Blake expressed his opinion that one of the specimens was certainly *Exogyra sinuata*.

of the Calley Farm lane. Now over the greater part of this breadth the ploughed soil shows nothing but limestone-fragments and some flints. The only field in which the ferruginous sands occur is the squarish one previously described, and that lies on and beyond the north-eastern limit of the outlier as mapped. Moreover, if only six feet of sands were present at Morris's pit, as he states, the fall of the ground thence to the next field to the south-west would take us at once on to the Portland beds. Of the north-west and south-east extension of the outlier I cannot speak, nor of the further patch passing under the Gault at Bishopstone. This last is the only point where the Bishopstone beds are shown on the Survey map as underlying the Gault at its outcrop, but, as already mentioned (p. 34), I have seen an exposure of them, close to the Gault, at Bridgefoot Farm, near Ford.

Westwards from Stone comes another long outlier, capping the high ground along which runs the road from Aylesbury to Thame. The ferruginous and pebbly sands are everywhere to be seen in the fields, but about the highest part of the ridge they are capped by sandy clays, mapped as Gault on the one-inch maps, but probably answering to the top beds in the Windmill section, Stone (see p. 55, later). These beds are worked at Haddenham Low brickfield.

At Haddenham several outliers are mapped, and the soil by the eastern windmill seems to indicate the existence of an extra one there.

HAZELEY TO RYCOTE.—I include the sands which crop out beneath the Gault along this line in the Bishopstone Beds on general stratigraphical grounds, but without any palæontological evidence that they are marine. In the fact that they follow the Gault outcrop we have a suggestion of conformity to that formation, and the great lithological difference between these beds up to their easternmost appearance at Rycote and the beds at Thame, which I class as freshwater, lead me to regard these as a different series.

According to the Survey map they begin about a mile south of Great Hazeley with a duplicated outcrop due to a strike-fault, and they cover a considerable area around Great Hazeley itself, thence running with a sinuous outcrop by Great Milton to the south side of the valley of the Chilworth Farm Brook, where they are overlapped by the Gault; two windmill-marked outliers on the left bank of the Thame forming a link towards the Combe Wood outlier.

I cannot myself speak for any point south of Great Hazeley: on the north side of that village the old stone-pits described by Fitton are certainly capped by ferruginous sands, but I could see no evidence of their presence in the village itself; on the contrary, there is what seemed to me to be an outcrop of limestone in the

roadway, and in the little quarry described on p. 30 the limestone came immediately under the soil. Some alteration in the mapping, therefore, seems necessary here. I have also been over the ground occupied by the southern of the two "windmill" outliers, and to judge from the soil of the fields it is much smaller than is shown on the map.

To return to the main outcrop, we find the beds well exposed at the stone pit, Great Milton (p. 29, *ante*). The main face now being worked faces due west, and shows the section given by Mr. H. B. Woodward in his Jurassic Memoir, viz.:

	ft.	in.
Brown loamy soil.		
Sand with bands of white and ochreous clay, with lignite ... ... 3 ft. to	6	0
Buff and white false-bedded sand with ferruginous layers and concretions; with at base lydite pebbles and ironstone ... ... 3 ft. to	6	0

In an old face to the north-west the sandy beds are very thin, only about 4 inches occurring between the upper sands and clays and the ironstone with pebbles (7 inches), below which again is clay (2 inches). On another face, half way between these two, the sands have increased to 2 feet 8 inches, and the bottom clay has disappeared. These facts illustrate the rapid variation in these beds.

The "Lower Greensand" is shown on the Survey map as overlapped by the Gault where this runs out along the ridge followed by the main road from London to Oxford; but descending from this ridge along the footpath by Trindal's Farm, a little below the 300 feet contour, one finds a most distinct outcrop of coarse pebbly sand, exactly like that seen on the other side of the ridge. There is much Drift about here, and I could not recognise this sandy outcrop by Chilworth Farm. Still, the "Lower Greensand" certainly extends beyond the limit marked on the Survey map, and this suggests the possibility that it may follow the Gault outcrop continuously round by Long Ground Farm. I have ventured to mark it as continuous on Fig. 1, though I have not actually traced it.

On the other side of the ridge it can be traced pretty continuously from Sandy Lane (south of Tiddington Station) by Tiddington village and Albury to near Rycote Pond. All along this line it rests on the Kimeridge Clay, and springs mark the boundary at Tiddington and Rycote. Beyond this latter point I have not traced it. According to the one-inch geological map and explanatory memoir there is a continuous narrow outcrop, largely concealed by Drift, from here to beyond Thame; but the new Index Map shows it as ending at Rycote. If the former were correct, "Lower Greensand" ought to have been shown in the railway-cutting near Rycote Pond described by Mr. Codrington;

but that showed river-gravels resting directly on Kimeridge Clay, Rycote Pond itself, a large sheet of water covered largely by weeds and haunted by wild fowl, certainly rests on clay—Gault, according to the one-inch map, Kimeridge, according to the Index Map. I mention this to show the difficulties of mapping in this area, where nothing seems to intervene between two great clays, where Drift is plentiful, and exposures few.

Correlation of the "Lower Greensand."

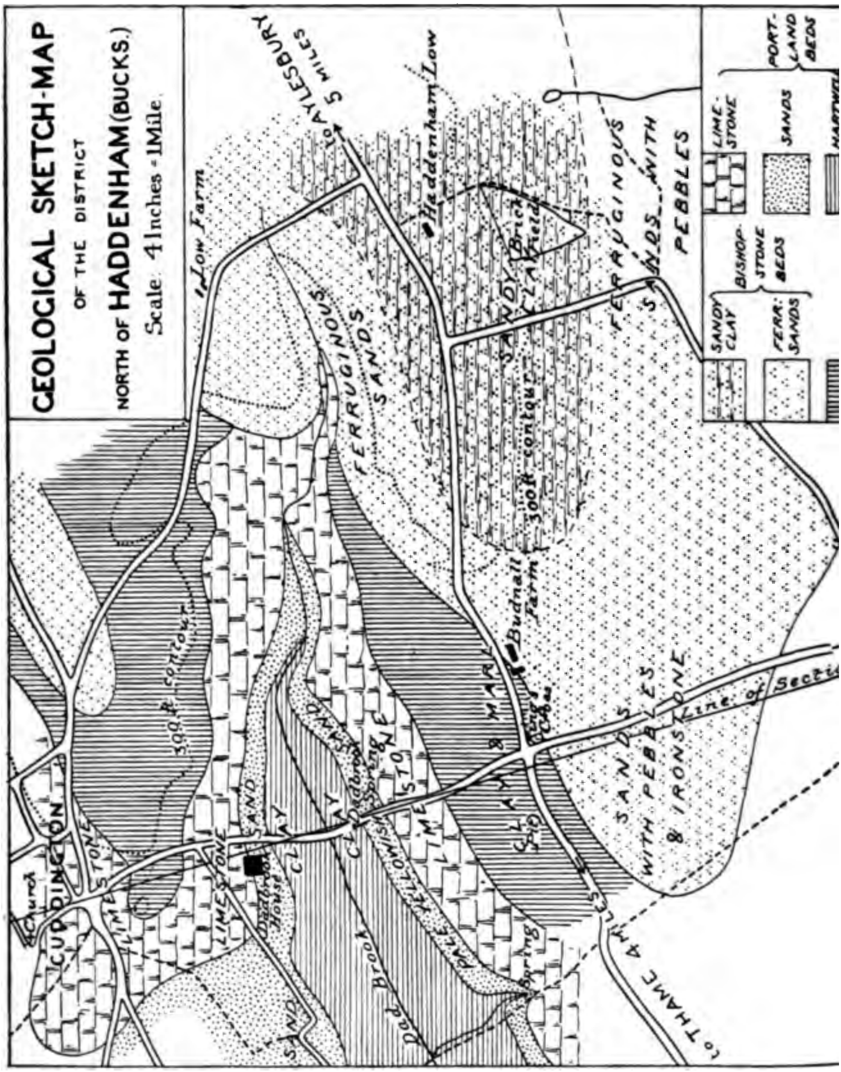
Just beyond the north-eastern boundary of the Thame Valley the continuous outcrop of the marine Woburn Sands begins Just at its south-western limit, the marine Toot Baldon sands appear. In the intervening area, in association with the *presence* of higher Jurassic beds than in adjoining areas, we find an *absence* of the continuous Lower Cretaceous beds, and instead we have an irregular series of patches, some marine, some freshwater.

Do the marine and the freshwater beds in the area represent simply two facies of beds of the same age, such as we might get in a large estuary? or are there here two or more formations of different ages? In favour of the former view is the absence of any section showing the freshwater beds overlain by unconformable marine beds; but did such a section exist, it might easily be taken, in the absence of fossils, as showing merely a contemporaneous erosion. Indeed, the section at the Windmill, Stone, might very well be so interpreted but for the occurrence of marine fossils at the very base of the sands not far off.

In favour of the second view, we have Morris's derived blocks with freshwater fossils. But these might be derived from some freshwater deposit of earlier date than the Shotover beds. There is also the close approach of the Toot Baldon sands to the neighbourhood of the Shotover beds, without any sign of passage between them; but against this must be put the absence at Toot Baldon itself of any sign of littoral conditions and derived blocks, such as we might expect if the sea in which they were deposited was attacking a shore-line only a mile away.

There is one other point to be considered. As our President (Mr. Teall) long ago pointed out, the freshwater beds always rest on Portland or Purbeck, while the marine ones may rest on lower beds. The only possible exception to this (now that the supposed overstep at Wheatley is disposed of) is the outlier at Forest Hill, and it is not impossible that the sands there may be marine. If this distinction holds good, it suggests that the Shotover beds are earlier in date than the earth-movements which gently folded the Portland beds and led to the Gault overstep.

I incline, on the whole, then, to the view that the Shotover beds are earlier in date than the marine beds. Of these, the Toot


GEOLOGICAL SKETCH-MAP
OF THE DISTRICT
NORTH OF HADDENHAM (BUCKS.)
Scale 4 Inches = 1 Mile
to AYLESBURY 5 MILES
Low Farm
Haddenham Low
FERRUGINOUS SANDS
SANDY CLAY
Brick Field
300 ft contour
Budnall Farm
FERRUGINOUS SANDS WITH PEBBLES
CLAY & MARL
SANDS WITH PEBBLES & IRONSTONE
Line of Section
CUDDINGTON
Church
LIMESTONE
SAND
CLAY
PALE YELLOWISH LIMESTONE
Dadbrook House
Dadbrook Spring
Dad Brook
Spring
to THAME 4 M.
LIME-STONE
SANDS
SANDY CLAY
FERR. SANDS
BISHOP-STONE BEDS
PORT-LAND BEDS

Baldon beds on the one hand, and the Woburn sands on the other, represent, on the whole, less littoral conditions than the Bishopstone beds, but the three may be of the same date. In Aptian times, when the sea reinvaded this area, the Portland beds, bent into a gentle basin with subsidiary N.W. to S.E. flexures, may have formed at first an isthmus, uniting the land of London with that of the north-west. Marine erosion may have reduced this to a peninsula, or an island, or a group of islands; and the Bishopstone beds may have been deposited in the inlets made by the conquering sea along the anticlinals of the land. But the final conquest came not by destruction, but by submergence. As the land sank, the formation of littoral deposits became less and less important, until finally, in the time of *Hoplites interruptus*, the Gault sea spread its blue mud directly on the older rocks—though the abundance of phosphatic nodules indicates a period of unrest at first.

V.—GAULT.

I shall dismiss the Gault in a few words, as I propose to deal with certain questions relating to it in a separate paper. The main outcrop can be traced from the Aylesbury district to Culham on the Thames. There are not many exposures, but where the base is seen it belongs to the zone of *Hoplites interruptus*, as at Folkestone.

Supposed Outlier at Haddenham Low.—Besides the outlier at Long Crendon (see p. 22 and Plate II.), two others are marked on the Survey maps as resting on the outlier of "Lower Greensand" (Bishopstone beds) that extends from near Haddenham to near Upton. The larger and more northerly of these is shown as overlapping the Lower Greensand, so as to rest on Portland Stone for a distance of nearly three-quarters of a mile. In the explanatory memoir to Sheet 45 it is stated that Gault is shown at the Kiln (Haddenham Low).

Of the smaller of the two outliers I cannot speak positively, but I have traversed the greater part of the ground occupied by the larger one, and am convinced that it has no existence. The clay exposed at Haddenham Low is a very sandy clay, exactly like that of the Windmill section at Stone. On washing, it leaves an enormous residue of pure white sand, without either foraminifera, glauconite-grains, or *Inoceramus*-prisms, such as abound in the true Gault of Long Crendon. I have no doubt whatever that this is the uppermost sandy clay of the Bishopstone beds.

In the portion of the supposed Gault which overlaps the Lower Greensand and rests directly on the Portland, the King's Cross pit (p. 40) has been opened, and we can see that what was taken for Gault here is really Purbeck clay. Over the area south of the Haddenham Low brick-kiln I could find no sign of clay at all;

everywhere the soil was that typical of the ferruginous sands of the Bishopstone beds.

My interpretation of the area is given in the sketch-map, p. 54. I make no claim to having traced the boundary-lines over the actual ground. They were drawn in consideration of a large number of scattered observations, and several traverses in different directions, and with the assistance of the contour-lines. The lines drawn for the Purbeck and Bishopstone beds north of the Dadbrook valley are purely hypothetical, so far as I am concerned, as they were drawn in accordance with the published Survey map and the run of the contour-lines.

After I had come to my own conclusion as to the non-existence of Gault in this area, I noticed that the outlier in question is omitted from the Index Map, Sheet 12. It appears, however, on the International Geological Map of Europe, Sheet B4, just published. In the explanation of Horizontal Section, Sheet 140, Mr. Jukes-Browne speaks of the clay exposed at Haddenham Low as belonging to the Lower Greensand. The Index Map, however, shows Lower Greensand as resting on the Portland west of King's Cross, in the area really occupied by Purbeck.*

VI.—PHYSIOGRAPHY OF THE DISTRICT.

It is necessary now to consider the origin of the peculiar course of the Thame in relation to the Portland and Gault (see pp. 17 and 35). This course appears to me to confirm the view of Prof. W. M. Davis, that the rivers of Eastern England are in the mature stage of a second cycle of activity. The clue to the puzzling course of the Thame is, I suggest, to be found in the fact that, though its course at present is mainly on Kimeridge Clay, it is properly a Gault stream. Before the last geocratic movement by which the English rivers were rejuvenated, the Thame meandered on a plain of Gault, some way to the north-west of its present course, and at a considerably higher level (250 to 300 feet). Its valley was bounded to the north-west by the rise of the ground towards a low escarpment of Portland beds and "Lower Greensand," which ran from Shotover Hill north-eastwards to Muswell Hill, and then gradually curved eastwards with the strike, to Quainton, Oving, and Cublington, where it died down as the Cretaceous overstep was completed. Whether this escarpment was actually continuous for the whole distance is difficult to say; the break in continuity of the present Portland outcrop between Hazeley and Thame suggests, but

* At the meeting at which this paper was read, the President announced that Mr. Jukes-Browne had recognised the non-existence of this Gault outlier when he revised the mapping in 1887.

does not prove a corresponding disappearance in the escarpment between Shotover and Muswell Hills. If it did not completely die away between these points, it may have been lower, owing to the Portland beds being thinner, or it may have been recessed for some distance with the change of strike caused by the pre-Cretaceous anticline which led to the break in the main outcrop.

When the second cycle of denudation began, the rejuvenated Thame rapidly cut its bed down, while at the same time it shifted itself as a whole in the direction of the dip of the Gault. But the former action was more powerful than the latter, and soon the stream had cut through the cover of Gault and struck upon the hidden rocks beneath. The curves in which it had been meandering now became fixed, and at the same time the dipward shifting was checked, owing to the harder character of the rocks it now had to erode. But at the two ends of the stream, where no Portland beds underlie the Gault, the dipward shifting continued, and thus the whole stream came to be drawn out into a loop—beginning and ending on Gault, and cutting down through Lower Greensand and Portland beds to Kimeridge Clay in the middle.

Meanwhile the Portland escarpment had suffered attack from both sides, by the tributaries of the Ray as well as those of the Thame. Being capped by such a thin layer of harder beds, it readily yielded to the attacks, and became cut up into isolated outliers, the Thame basin gaining on that of the Ray between Shotover and Muswell Hill, and still more strikingly between Oving and Cublington; while the Ray gained ground between Muswell Hill and Quainton. Hence comes the irregularity of the north-western boundary, pointed out at the beginning. That in Shotover, Muswell, Quainton, and Oving Hills we have disintegrated parts of an escarpment seems clearly shown (1) by the uniformity of their structure—everywhere capped by Lower Greensand, never by Gault, as is the differently-produced outlier of Long Crendon; (2) by their disposition along a curving line of strike; (3) by the gradual drop in the height from Quainton to the vanishing point at Cublington, which was so low that here alone glacial drift obtained entrance into the Thame valley; and (4) by the flat-topped character of the largest of them, viz., Shotover and Oving outliers.

I expect and hope that these views, as well as others put forward in this paper, may meet with criticism; and I trust that before long the members of the Association will have an opportunity of discussing matters with me on the actual ground.

REMARKS UPON THE OSTRACODA.

By F. CHAPMAN, A.L.S., F.R.M.S.

THE majority of the Ostracoda here noticed are well-known Lower Purbeck forms.*

There are, however, some other species of much interest, which call for special comment.

Bythocypris winwoodiana, Jones and Sherborn; *Proc. Bath N. H. and Antiq. F. Club*, 1888, vol. vi, No. 3, p. 252, pl. V, figs. 1 *a–c*.

This species was originally described from the blue Fuller's-Earth Clay of Midford. A single specimen is here recorded from a green clay of uncertain horizon, but probably Portlandian, at Denham Hill Farm, near Quainton.

Macrocypris horatiana, Jones and Sherborn; *Proc. Bath N. H. and Antiq. F. Club*, 1888, vol. vi, No. 3, p. 252, pl. V, figs. 2 *a–c*.

It is interesting to note the occurrence of this species as being in some abundance in the Aylesbury district, having been previously found in the blue Fuller's-Earth Clay at Midford.

M. horatiana is here recorded from King's Cross, Bed No. 3, at the bottom; and from a pit $\frac{3}{4}$ mile from Walton (Aylesbury) along Bishopstone footpath, Bed 4.

Cythere drupacea, Jones; *Quart. Journ. Geol. Soc.*, 1884, vol. xl, p. 772, pl. XXXIV, fig. 30. *Cytheropteron drupaceum* (Jones), Chapman, 1894, *ibid.*; vol. l, p. 691. *Cythere drupacea* (Jones), Chapman, 1897; *Proc. Geol. Assoc.*, vol. xv, p. 96.

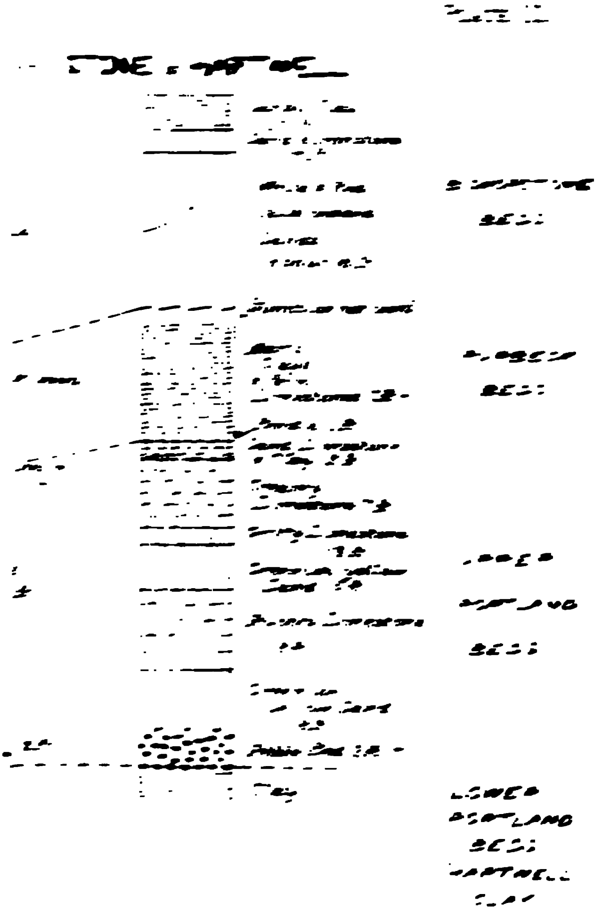
This species has been found in the Great Oolite of the Richmond Well-boring, in the Hartwell Clay of Aylesbury, and in the Bargate beds (Aptian) of Guildford [perhaps derived].

Some of the Jurassic examples from the Aylesbury district now under examination are exceptionally tumid in the postero-ventral region. *Cythere drupacea* occurs in all the samples from King's Cross, Bed No. 3, and in some abundance.

Cytheridea (?) *subeminula*, Jones and Sherborn; *Proc. Bath N. H. and Antiq. F. Club*. 1888, vol. vi, No. 3, p. 261, pl. V, figs. 8 *a–c*.

A specimen from Coney Hill, Bed 5, agrees somewhat nearly with the above species, but being slightly damaged it is difficult to say with certainty. Messrs. Jones and Sherborn described this species from the base of the Fuller's-Earth Oolite between Notgrove and Bourton.

* See T. R. Jones, *Quart. Journ. Geol. Soc.*, vol. xli, 1885, p. 311; also F. Chapman, *Proc. Geol. Assoc.*, vol. xv, 1897, p. 96.



REMARKS UPON THE OSTRACODA.

By F. CHAPMAN, A.L.S., F.R.M.S.

THE majority of the Ostracoda here noticed are well-known Lower Purbeck forms.*

There are, however, some other species of much interest, which call for special comment.

Bythocypris winwoodiana, Jones and Sherborn; *Proc. Bath N. H. and Antiq. F. Club*, 1888, vol. vi, No. 3, p. 252, pl. V, figs. 1 *a–c*.

This species was originally described from the blue Fuller's-Earth Clay of Midford. A single specimen is here recorded from a green clay of uncertain horizon, but probably Portlandian, at Denham Hill Farm, near Quainton.

Macrocypris horatiana, Jones and Sherborn; *Proc. Bath N. H. and Antiq. F. Club*, 1888, vol. vi, No. 3, p. 252, pl. V, figs. 2 *a–c*.

It is interesting to note the occurrence of this species as being in some abundance in the Aylesbury district, having been previously found in the blue Fuller's-Earth Clay at Midford.

M. horatiana is here recorded from King's Cross, Bed No. 3, at the bottom; and from a pit $\frac{3}{4}$ mile from Walton (Aylesbury) along Bishopstone footpath, Bed 4.

Cythere drupacea, Jones; *Quart. Journ. Geol. Soc.*, 1884, vol. xl, p. 772, pl. XXXIV, fig. 30. *Cytheropteron drupaceum* (Jones), Chapman, 1894, *ibid.*; vol. l, p. 691. *Cythere drupacea* (Jones), Chapman, 1897; *Proc. Geol. Assoc.*, vol. xv, p. 96.

This species has been found in the Great Oolite of the Richmond Well-boring, in the Hartwell Clay of Aylesbury, and in the Bargate beds (Aptian) of Guildford [perhaps derived].

Some of the Jurassic examples from the Aylesbury district now under examination are exceptionally tumid in the postero-ventral region. *Cythere drupacea* occurs in all the samples from King's Cross, Bed No. 3, and in some abundance.

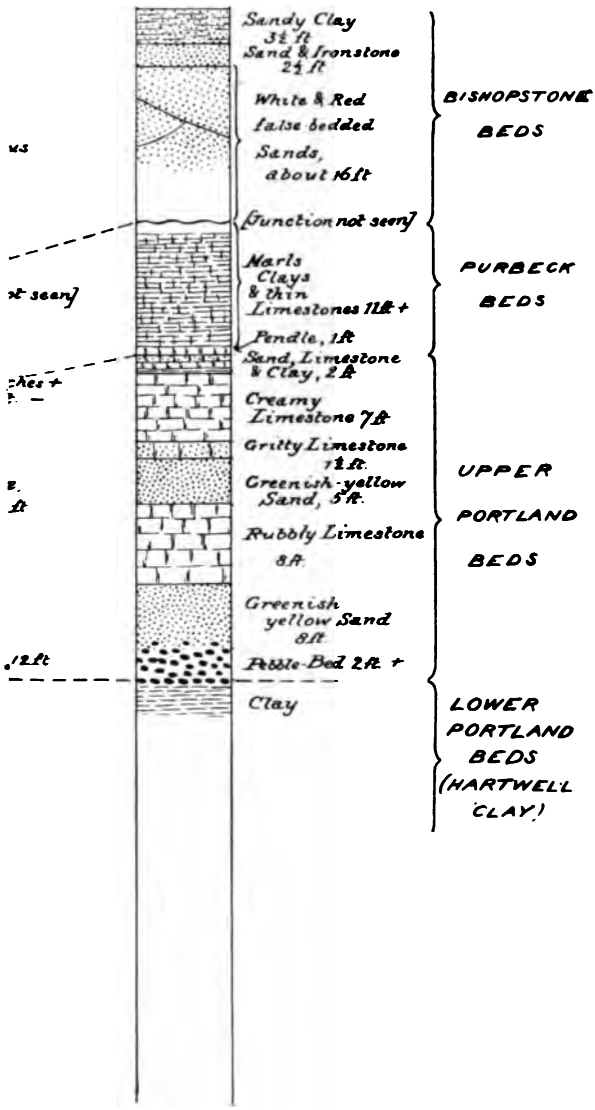
Cytheridea (?) *subeminula*, Jones and Sherborn; *Proc. Bath N. H. and Antiq. F. Club*. 1888, vol. vi, No. 3, p. 261, pl. V, figs. 8 *a–c*.

A specimen from Coney Hill, Bed 5, agrees somewhat nearly with the above species, but being slightly damaged it is difficult to say with certainty. Messrs. Jones and Sherborn described this species from the base of the Fuller's-Earth Oolite between Notgrove and Bourton.

* See T. R. Jones, *Quart. Journ. Geol. Soc.*, vol. xli, 1885, p. 311; also F. Chapman, *Proc. Geol. Assoc.*, vol. xv, 1897, p. 96.

PLATE II.

.ES STONE & HARTWELL



VALLEY.

Scale : 1 inch = 20 feet.

ORDINARY MEETING.

FRIDAY, NOVEMBER 4TH, 1898.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

The following were elected Members of the Association: G. Reeve, jun., John Theodore Hewitt, M.A., etc.

The evening was then devoted to a Conversazione, and the following is a list of the exhibitors and their exhibits:

THE PRESIDENT: Specimens illustrating the artificial production of the structures of Gneissose rocks by the deformation of heterogeneous masses of clay, and photographs of similar structures in the Gneissose rocks of the Lizard Peninsula; Sections of artificial rocks and minerals prepared by Messrs. Fouqué and Lévy; Micro-photographs of wollastonite-spherulites in bottle glass; and Plates to illustrate the Memoir on the Silurian Rocks of Scotland, by Messrs. B. N. Peach and John Horne.

H. W. BURROWS and R. HOLLAND: A large series of photo-micrographs of recent and fossil Foraminifera.

THE DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY: Recently issued Maps and Memoirs of the Geological Survey.

J. SLADE: Specimens of wavellite from Barnstaple.

HORACE B. WOODWARD: An old print from a drawing by De la Beche, and a representation of Dr. Buckland, drawn by Thomas Sopwith.

J. D. HARDY: Objects shown under the microscope by the aid of the exhibitor's "Chromatoscope."

E. T. NEWTON: A new Dinosaurian from the Rhætic of Glamorganshire, found by John David; and a series of forged flint implements.

W. P. D. STEBBING: A copy of "Meteorologia et Oryctographia Helvetica," by Joh. Jacob Scheuchzer, Zurich, 1718, with folding plates; specimen of Bryozoa Bed, Lower Limestone Shales, Portishead; Hyolite Limestone from the Lower Cambrian of Nuneaton; and silicified wood from Edmonton, N.W. Canada.

PROF. T. G. BONNEY: Apatite and associated rocks from Canada.

MISS C. A. RAISIN: Rock specimens from Switzerland and from the Vosges.

GEORGE POTTER: Some of the early circulars of the Association, including the first circular issued; a portrait of Mr. Toulmin Smith, the first President; and some interesting old prints including a representation of Dr. Bowerbank's house in Highbury Grove. (*The above were of special interest on this occasion, as the Association now completes the 40th year of its existence, the first meeting having been held on the 17th November, 1858.*)

G. E. DIBLEY: Some rare and undescribed fossils from the Chalk.

JOHN N. TERVET: A fossil Fish from the Oil Shales of Sao Paulo, Brazil; fossils from the Oil Shales of Australia, and from Tarbrax, Lanarkshire.

REV. PROF. J. F. BLAKE: A fine collection of Jurassic Ammonites from Russia and from India.

PERCY EMARY: Specimens and micro-sections of rocks from the Urals.

F. R. B. WILLIAMS: A series of fossils from Hythe and neighbourhood.

W. F. GWINNELL: Large land Mammals dredged from the Dogger Bank in the North Sea, including remains of Mammoth, Reindeer, and *Bos primigenius*; *Nummulites* and nummulitic limestones from the Isle of Wight, Belgium, Malta, Egypt, and India, including some exceptionally large specimens.

S. HAZZLEDINE WARREN: A series of flint implements from the Thames and Lea Valleys, including examples of Eolithic or Plateau type, and of the Earlier, Middle, and Later Palæolithic forms.

A. E. SALTER: Specimens (other than flint) illustrating the constitution of the gravels of the Early Drifts of the South and East of England.

F. A. BATHER: Specimens, plaster casts, and drawings of *Petalocrinus* from the Silurian Rocks of Iowa and Gotland, being a large part of the material described in the *Quarterly Journal of the Geological Society*, vol. liv, pp. 401-441, Pls. XXV and XXVI, August, 1898.

A. S. KENNARD: Palæolithic Implements from West Wickham, Kent.

BENJAMIN HARRISON: A series of Plateau and Palæolithic Implements arranged to show the persistency of the types.

FRANK LASHAM: Palæolithic Implements from Farnham, Surrey.

D. A. LOUIS: Iron ores and associated rocks from Küranavara and Gellivara, Lapland; photographs showing the character of that country and of the deposits and modes of working them; specimens of iron ores from Persberg, Central Sweden, and of the metal produced from them.

J. HOPKINSON: Sections of Mount Sorrel granite, garnetiferous gneiss from Perth, and Hebridian gneiss from Hannan Islands, shown in polarised light under the microscope,

MARTIN A. C. HINTON: Remains of a fossil horse (*Equus caballus*) from the High Terrace Gravel of Wanstead; ard samples of psilomelane found in a continuous seam at the same place.

G. FLETCHER BROWN: Fossils from the Chalk and London Clay.

J. FRANCIS: A collection of Jurassic fossils from Whitby.

G. ABBOTT: Segregation in mortar, honeycomb limestone, and concretions, spherical flints with kernels, and ripple marks in limestone.

R. ELLIOTT: A case containing Hugh Miller's favourite hammer; and fossil fish from the Old Red Sandstone; flint implements from Canada and Tasmania; specimens from a Saxon interment in Suffolk; tooth of *Elephas primigenius* and a fine specimen of *Ptychodus*.

UPFIELD GREEN: Skiagraph of crinoids in slate; folded purple slates, brecciated slates, and ash beds from Cornwall; a large quartz crystal built up of smaller ones from Eiserfeld, near Siegen; fractured and re-cemented apatite crystal from Norway; and contorted gneiss from Septimer Pass, Casaccia, Engadine.

ORDINARY MEETING.

FRIDAY, DECEMBER 2ND, 1898.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

The following were elected members of the Association: W. H. Cooke, B.A., Ellis W. Heaton, Henry Hendriks, H. Kidner, H. J. Leaning, and J. M. V. Money-Kent.

A paper was read by Mr. A. Morley Davies, A.R.C.S., B.Sc., F.G.S., entitled "Contributions to the Geology of the Thame Valley." The paper was illustrated by maps, sections, and specimens, and by some excellent photographs taken by Mr. J. H. Pledge. By the kindness of Prof. Bonney, a series of fossils collected from the district by the late Prof. Morris was also exhibited.

THE NATURAL HISTORY OF CORDIERITE AND ITS ASSOCIATES.

By J. J. H. TEALL, M.A., F.R.S., F.G.S.

(Presidential Address, delivered February 3rd, 1899.)

DURING the last thirty years an extraordinary outburst of petrological activity has taken place in consequence of the application of precise mineralogical methods to the study of rocks. The petrologist, and through him the geologist, owes therefore, an enormous debt of gratitude to the mineralogist; but while acknowledging this debt, I desire to point out that the benefits, due to the more intimate union between geology and mineralogy which has thus been established, are not wholly one-sided. If petrology owes much to mineralogy, it has in its turn conferred benefits upon the latter science. Striking evidence of this is furnished by the important work on the mineralogy of France and her Colonies by Professor Lacroix, who is not only a mineralogist but a distinguished petrographer and geologist. This book, unlike the older mineralogies, is not a mere catalogue of the crystallographic, chemical, and optical characters of museum specimens, but a series of monographs in which the different minerals are treated from all points of view, and in which due importance is attached to their modes of occurrence and origin. This welcome change is, it seems to me, largely due to the influence of petrology upon mineralogy.

Let me try to illustrate the advantage of studying minerals from what may perhaps be termed the natural history point of view, by giving some account of a small group which has attracted my attention at intervals during the last few years. I refer to the "faithful companions"—corundum, spinelle, sillimanite, and cordierite.

Corundum is crystallised alumina (Al_2O_3) and is therefore the simplest of the four in composition. Its crystals belong to the hexagonal or rhombohedral system, and vary in habit and colour according to their mode of occurrence. Many beautiful gems such as ruby and sapphire are merely varieties of corundum.

True spinelle is an aluminate of magnesia (MgO,Al_2O_3), and, like all the members of the group, crystallises in the cubic system in the form of octahedra. Between true spinelle and magnetite (FeO,Fe_2O_3) there are many intermediate varieties in which ferrous iron takes the place of magnesium and ferric iron that of aluminium in almost any proportion; so that the general formula for the group, excluding the chrome-spinelles, to which I

do not propose to refer, may be written $(MgFe)O,(Al_2Fe_2)O_3$. These intermediate forms are usually green in colour, the depth of tint increasing to opacity as the amount of iron increases. As it is impossible to distinguish different varieties, such as pleonaste and hercynite, under the microscope they will simply be referred to as green spinelles.

Sillimanite is the simple silicate of alumina (Al_2O_3, SiO_2). It crystallises in the rhombic system as long slender prisms, which are often so thin as to appear like needles or hairs under the microscope.

Cordierite is a silicate of alumina and magnesia with some iron replacing the magnesium ($2MgO,2Al_2O_3,5SiO_2$). It may be said to bear the same relation to spinelle that sillimanite does to corundum. Thus sillimanite is corundum plus silica; and cordierite is spinelle plus silica. Cordierite crystallises in the orthorhombic system, and is found under two conditions. In the gneisses and contact-rocks it occurs, as a rule, in irregular colourless grains which are not pleochroic in thin sections, except a round minute inclusions of zircon. In this form it is often crowded with needles of sillimanite, and not infrequently contains also small and more or less rounded scales of biotite.

In volcanic rocks it often occurs as six-sided prisms, cross sections of which break up into sectors in polarised light. There is thus a marked difference in habit between the cordierite of the gneisses and contact-rocks, on the one hand, and that of the volcanic rocks on the other. The cordierite of the volcanic rocks is, moreover, often pleochroic.

Now these minerals, usually in combinations of two or more, occur under the most diverse geological conditions. They are found:

1. As the constituents of foliated crystalline rocks belonging to the so-called Archæan formation.

2. As the products of contact-metamorphism round plutonic masses.

3. As the constituents of inclusions in (*a*) plutonic igneous rocks, (*b*) dykes, and (*c*) volcanic rocks, including both lavas and agglomerates.

4. As the direct products of the crystallisation of natural silicate-magmas.

5. As the direct products of the crystallisation of artificial silicate-magmas.

It is impossible within the limits of this address to do more than refer to one or two typical examples of each of these modes of occurrence.

Cordierite-gneisses are found in many parts of the world in association with other foliated crystalline rocks, and also not infrequently in the neighbourhood of granites containing cordierite into which they are said to pass. Bodenmais, in

Bavaria, is one of the best known localities. Here cordierite occurs in connection with sillimanite, biotite, quartz, iron-ores, garnet, and sometimes also with orthoclase and oligoclase. The sillimanite may be either crowded together in clots or bundles, or may occur as inclusions in the cordierite, and sometimes also in the other minerals. The cordierite is irregular in form and colourless, with yellow pleochroic halos round zircons; but it does not show the division into sectors or the pleochroism which are so characteristic of the cordierite of volcanic rocks.

Similar rocks occur in the granulite region of Saxony, at Tvedstrand in Norway, in the Central Plateau of France, and many other localities.

Various views have been expressed as to their origin. Some are content simply to refer them to the Archæan system; others regard them as due to the contact or thermo-dynamic metamorphism of ordinary argillaceous sediments; and others as rocks of mixed origin, that is as rocks containing both igneous and sedimentary material.

The last view, although it is certainly not applicable to all cases, deserves more than a passing notice, for where cordierite-bearing rocks occur as contact products they usually belong to the inner zones and sometimes give distinct evidence of the intimate intermixture of granitic and sedimentary material. If mixed rocks of this kind were foliated by deformation they would unquestionably produce cordierite-gneisses.

Cordierite-bearing rocks, often containing sillimanite and spinelle, have been recognised at many points in the Eastern Highlands in the counties of Aberdeen, Banff, and Forfar. A general account of these rocks was given in the Explanation to Sheet 75. I will quote a description of a specimen from the top of the Buck of Cabrach collected by Mr. Hinxman.

"This is a massive, dark, bluish rock spangled with small flakes of white mica. It possesses a somewhat spotted appearance in consequence of the presence of individuals or aggregates of cordierite. The colourless constituents, cordierite, andalusite, white mica, microcline and quartz, make up the main mass of the rock. The dark minerals are magnetite and biotite, but the latter is very feebly represented. Cordierite, andalusite and white mica usually contain numerous inclusions of magnetite and quartz and thus show the micropoikilitic structure which is so common in contact minerals. All the massive cordierite-bearing rocks show a characteristic bluish-grey colour, but they vary in composition. A specimen from the railway cutting south-east of Little Arnage is of considerable interest as throwing light on a subject I have already referred to. It is evidently a compound rock due to the superposition of igneous upon metamorphic material. The igneous portion is represented by more or less idiomorphic oligoclase, biotite, orthoclase and quartz; the

metamorphic portion by cordierite, quartz, biotite, sillimanite, iron ores and a green spinelle. The rock into which the granitic magma was intruded is now represented by somewhat ill-defined shreds, patches, and streaks in a paste of igneous origin."

Since the Explanation of Sheet 75 was published other specimens of the same type of rock have been sent up for examination by Mr. Barrow and Mr. Kynaston. Mr. Barrow's specimens were collected in the Glen Muich area, and one of these, composed of cordierite, sillimanite, quartz, biotite, iron-ores, green spinelle, and probably a little felspar, was analysed. It contained, as might naturally be inferred from its mineralogical composition, a very high percentage (32·4) of alumina. Mr. Barrow looks upon the rock as the result of the general thermo-metamorphism which has affected the Eastern Highlands and which was associated with the intrusion of the earlier granitic material. Mr. Kynaston's specimens come from the neighbourhood of the Ben Cruachan granite and are regarded by him as normal contact-rocks due to this mass of granite. They are medium grained, dark, bluish grey, fairly massive rocks, composed of cordierite, andalusite, alkali-felspar, oligoclase, biotite, pyrite, and a green spinelle. Quartz is sometimes, but not always, present.

In describing rocks of this type from the Eastern Highlands, I have more than once called attention to the fact that corundum might naturally be expected to occur in them, but that it could not be detected in the thin sections. The presence of a colourless grain which might possibly be corundum in one of the slides of a specimen from the neighbourhood of Ben Cruachan led me to examine the rock in another way. The coarse powder was placed in hydrofluoric acid and allowed to digest for several days, with the result that corundum was found in the residue together with pyrite, spinelle, and a few crystals of rutile that had escaped notice in the slide.

The corundum in this rock occurs in crystals and more or less irregular grains. The crystals are combinations of the hexagonal prism, the primitive rhombohedron, and the basal plane. They are sometimes flat and sometimes prismatic. The flat forms in which the prism is feebly developed are frequently stepped on the basal plain owing to the repeated alternations of this face with the faces of a rhombohedron. This habit is not unfrequent in corundums. It may be seen in some of the Burma rubies and is a marked feature of the Montana "sapphires."

A very interesting case of the occurrence of all four minerals in rocks produced by contact-metamorphism has been described by Salomon[18].* The important mountain mass of which Monte Adamello (11,681 ft.) forms the culminating point is situated in the southern portion of the Eastern Alps. It consists of a nucleus

*The small figures refer to the list of papers quoted at the end of the Addres

of tonalite or quartz-diorite surrounded by a girdle of sedimentary rocks of different ages, many of which show the effects of contact-metamorphism.

The rocks with which we are more immediately concerned form part of a zone following the western margin of the intrusive mass, along which they have been traced for a distance of fourteen kilometres. They represent portions of the older, more or less metamorphosed sedimentary rocks of the Alps which have been still further metamorphosed by the tonalite. The most characteristic rock of the inner zone consists of fifty, or very often of sixty or seventy per cent. of cordierite associated with various other minerals, including biotite, andalusite, sillimanite, quartz, titaniferous iron-ore, and, in certain special cases, plagioclase, orthoclase, garnet, spinelle, and corundum. There is often a most intimate association of the cordierite-bearing contact-rock and the igneous mass, and inclusions of the former occur in the latter.

So much for contact-rocks. We pass on now to consider other modes of occurrence. Inclusions containing two or more of the minerals in question, sometimes all four together, are found in plutonic masses, dykes, lavas, and agglomerates. They occur, for example, in the tonalite, to which I have just referred, in the kersantite dyke of Michaelstein in the Hartz[12], in andesitic lavas of the Eifel[13], the Siebengebirge[13], and the province of Almeria, in the south-east of Spain[14]; and, finally, in the ejected blocks of the Laacher See and of Asama Yama in Japan[15]. By piecing together the evidence furnished by different localities we seem to be able to trace these inclusions from their birthplace in the infernal regions to their final resting-place on the earth's surface. The subterranean magmas act powerfully on their containing walls, and transform highly argillaceous sediments into crystalline rocks composed of cordierite, sillimanite, biotite, quartz, and sometimes spinelle and corundum. The rocks of the inner contact-zone become shattered, and the igneous magma insinuates itself between the cracks, or may even permeate the mass. Portions of the metamorphic rock float off into the molten material and travel with it through dykes and other channels to the surface, where they form either inclusions in a lava or ejected blocks in an agglomerate, according to the conditions of the eruption. This, no doubt, is the explanation of the presence of inclusions containing the minerals in question in some cases, but it by no means supplies a full explanation of all the facts. Many of the inclusions, especially those found in dykes, lavas, and agglomerates, resemble fragments of cordierite-gneisses rather than normal contact rocks; others contain the minerals in a form different from that in which they occur either in the gneisses or the contact-rocks. To illustrate these points we must consider one or two typical cases.

The kersantite-dyke, near Michaelstein[6], is intrusive in clay-slate with subordinate layers of limestone, quartzite and kiesel-schiefer. The rock, which is dark-grey, almost black in colour, is composed of numerous phenocrysts of biotite and a few of felspar, set in a compact matrix. Under the microscope enstatite and cordierite may be recognised, and the latter mineral occurs in such a way as to prove that it must have crystallised from the magma. It forms sharply defined six-sided prisms, cross sections break up in polarised light into sectors—often six—and opposite sectors extinguish simultaneously. These features are not those of the cordierite of the gneisses or contact-rocks, and they undoubtedly prove that the mineral has been formed where we now see it. But the occurrence of authigenic cordierite is by no means the only peculiar feature of this remarkable dyke. It is crowded with minerals which are obviously foreign to the rock, including felspar, garnet, sillimanite, cyanite, quartz, biotite, rutile, spinelle, apatite, corundum, staurolite, hypersthene, calcite, magnetite, anatase, and titaniferous iron-mica. They occur either singly or in aggregates. Scarcely a slide or specimen can be found without one or more of them, and the aggregates vary from microscopic dimensions up to the size of a walnut, or even larger. In some cases half the rock is made up of foreign constituents.

Before dealing with the significance of these facts, let us consider one or two other cases of an allied nature. The hornblende-andesites of Bochsberg and Rengersfeld in the Eifel, described by Vogelsang[19], are not homogeneous in character. They contain masses which sometimes have the aspect of included fragments and sometimes that of streaks merely differing in character from the rest of the rock. The minerals of which these aggregates are composed are cordierite, andalusite, sillimanite, felspar, biotite, pleonaste, corundum, rutile, quartz, garnet, zircon, and magnetite—that is much the same association as that found in the foreign substances in the Michaelstein dyke. The aggregates, which are formed of somewhat variable combinations of the minerals I have mentioned, are sometimes easily separable from the matrix, at other times firmly welded to it. They vary in size from microscopic dimensions up to masses 6 cms. in diameter, or in the case of the streaks 12 cms. in length.

A very common type consists of a fine-grained, grey rock, essentially composed of cordierite, andalusite, sillimanite, and plagioclase. The cordierite is irregular in form, intensely pleochroic, and often twinned. It contains grains of rutile, needles of sillimanite, and inclusions of glass.

Andalusite is next to cordierite the most abundant constituent. Sillimanite occurs in fibrous aggregates between the other constituents, and also as inclusions within them. Biotite is

not uncommon, and is often found in association with a brown amorphous substance which appears to have been formed by the partial melting of the mineral. Pleonaste or green spinelle occurs in the inclusion, and is also found abundantly in well-formed octahedra in the andesite immediately surrounding the inclusion.

There can be no doubt that these inclusions have been derived either from the crystalline schists or from a contact-zone. Vogelsang, who has studied them in great detail, inclines to the former view. The occurrence of spinelle in the andesite immediately surrounding the inclusions is of special interest. This, like the cordierite in the kersantite of Michaelstein, undoubtedly owes its origin to the chemical change in the magma consequent on the solution of a certain amount of the material of the inclusions.

Another interesting case of a somewhat similar character occurs in the province of Almeria, in Spain[14]. The south-east coast of Spain, from Cabo di Gata to the neighbourhood of Carthagena, a distance of about two hundred kilometres, is bordered by a zone of volcanic rocks belonging to the upper Miocene or early Pliocene periods. They are not continuously exposed, but appear at intervals from beneath the upper Pliocene deposits.

This zone of volcanic action bears the same relation to the alpine folds of the mountains of Andalusia as do the volcanic rocks of the northern coast of Africa to the corresponding folds of the Atlas system, and as do the Tertiary volcanic rocks of Italy to those of the Apennines.

A plain of upper Pliocene rocks separates the Sierra Alhamilla, which belongs to the central zone, from the Sierra del Cabo di Gata which is formed entirely of volancic rocks. On the northern side of this plain are several small hills, one of which, Hoyazo, has a curious crater-like depression in the centre. This depression can be entered by following the course of a ravine which is about 200 yards long. The bottom of the depression is about 200 feet below the rim, which is almost circular, and about 350 yards in diameter. The lower part of the wall is formed of andesite and andesitic tuffs, the upper part (6-13 ft.) of marine limestone containing bivalves and gasteropods. In the upper part the slope is steep, often vertical; in the lower part, formed of the volcanic rocks, it is less steep. The limestone forms a mantle to the hill which was for a long time regarded as a typical crater of elevation. There is, however, clear evidence that the limestone was deposited on the igneous rocks, and that there has been no volcanic action since its deposition.

The volcanic rock is a mica-andesite. It contains phenocrysts of a basic plagioclase, biotite, rhombic pyroxene, and hornblende in a glassy base. But the most interesting constituent is

cordierite. This occurs in two forms—as irregularly bounded optically uniform grains up to the size of a hazel-hut, and as sharply defined idiomorphic crystals. The former are inclusions; the latter are crystals which have separated from the magma. In addition to the mineral inclusions there are also rock fragments varying in size from that of a head down to microscopic dimensions. These are (1) quartz blocks, (2) lumps of quartz and cordierite, and (3) fragments of cordierite-biotite-gneiss with garnet.

Osann, whose description I am quoting, points out that the extraordinary abundance of indigenous cordierite coupled with the presence of numerous inclusions of cordierite-gneiss lead to the conclusion that portions of the foreign rock have been dissolved and that a magma of exceptional composition, out of which cordierite has separated on cooling, has thus been formed.

We have now to consider the evidence furnished by ejected blocks.

The volcano of the Laacher See, like that of Vesuvius, is remarkable for the number and variety of the ejected blocks occurring in the agglomerates. They include fragments of crystalline foliated rocks, blocks mainly formed of sanidine, and fragments of trachyte; the two last being obviously connected with the magma. Of the crystalline schists, cordierite-gneisses are the most abundant. They occur in their normal condition, and also show the effects of the great heat to which they have been subjected during the eruption. Dittmar[3] divides the cordierite-bearing rocks into three classes: (1) cordierite-gneiss with sillimanite, (2) massive rocks containing newly formed felspar and cordierite, and (3) spotted schists.

In rocks of the first group, which show little or no alteration by heat, the cordierite is clear, very slightly pleochroic, and contains inclusions of spinelle and corundum. In rocks which have been acted upon it is strongly pleochroic and mostly free from sillimanite. It is also surrounded by a zone of glass, and contains secondary glass-inclusions. The biotite in these rocks has often been fused to a glass out of which spinelle has separated. In still more highly altered rocks the original minerals have entirely disappeared, and newly formed cordierite is seen lying in a matrix of brown glass.

Many other cases of a similar character might be quoted, but one must suffice. A basalt occurring near Kollnitz[17] in Carinthia, has involved fragments of an argillaceous rock and partially dissolved them. The normal basalt is composed of plagioclase, augite, olivine and magnetite, and is almost holocrystalline. The included fragments are associated with glassy streaks or schlieren, in which cordierite and spinelle have been formed. The partial solution of the fragments evidently modified the composition of the magma so that it cooled as a glass after cordierite and spinelle

had separated out. The story is the same as that told by the ejected blocks of the Laacher See, the andesites of Hoyazo and the Eifel, and the kersantite dyke of Michaelstein. It is very interesting to note that the addition of alumina to the basaltic magma has hindered its crystallisation. This effect of alumina in preventing crystallisation is well known to glass makers.

Corundum has been recorded as occurring in many igneous rocks, and in some of these it is undoubtedly indigenous. Professor Lagorio,[11] who was, I believe, the first to insist on the igneous origin of corundum, cites many instances, but unfortunately in several of these the mineral has certainly not crystallised out of the magma. Nevertheless, there are not a few well authenticated cases; for example, the corundum-pegmatites and corundum-syenites of the Urals [12] and the very remarkable corundum-syenites of Hastings County, Canada, recently discovered by the Geological Survey of the Dominion, and admirably described by Mr. Miller.[13] In all these cases the matrix of the idiomorphic corundum is formed of alkali-felspar, sometimes associated with nepheline. Moreover, the intrusive character of the Canadian rocks is quite clear.

Then, to come nearer home, there is the interesting case described by Professor Busz.[14] The mineral occurs in a felsite, intrusive in clay slates, near South Brent. It is present in extremely minute tabular crystals (·02-·03 mm.), sometimes showing hexagonal outlines, and is most abundant near the contact of the felsite with the clay slates. It is, no doubt, due, as Professor Busz states, to the fact that portions of the slates were dissolved by the felsitic magma, which became super-saturated with alumina on cooling, and thus gave rise to the formation of corundum.

Another apparently well-authenticated case, is that of the so-called Montana sapphires. The minerals were first found and worked in an auriferous glacial gravel near the head waters of the Missouri, but they were subsequently discovered by Mr. G. F. Kuntz in an igneous rock which Prof. Miers described as a vesicular mica-augite-andesite. Still later, corundum was found near Yogo Gulch, fifteen miles south of Utica, in a yellow, earthy material which could be traced across the country for a considerable distance in an east and west direction, and which evidently resulted from the alteration of an igneous dyke. In working downwards the unaltered igneous rock was reached and this has been described by Prof. Pirsson as a basic lamprophyre, consisting mainly of biotite and pyroxene. Speaking of the relation of the corundum crystals to the matrix Prof. Pirsson [15] says: "The clear-cut form of the crystals and their general distribution shows that they had crystallised out of the magma with as much certainty as the well-formed phenocrysts of felspar in a porphyry betray their origin." He explains the presence of the mineral by supposing that the original magma dissolved

portions of the "clay shales" of the district and thus, on cooling, became supersaturated with alumina.

If Prof. Pirsson's theory be true we have here a case of the formation of corundum in a basic magma containing lime-magnesia silicates. As will be seen later on there are some difficulties in the way of accepting this theory, but I am not sure that they are sufficient to destroy the force of the facts recorded by him.

We have now arrived at the last stage of our enquiry. A recently-published paper by Dr. Morosewicz,[13] of Warsaw, gives a complete or nearly complete account of the conditions under which the four minerals (corundum, spinelle, sillimanite, and cordierite) form in igneous rocks. The researches described in this paper extended over a period of five or six years, and the results obtained are, from a petrographical point of view, some of the most interesting that have appeared during recent years. They must rank in importance with the artificial production of igneous rocks by Messrs. Fouqué and Lévy.

The experiments were made in a Siemens' furnace in a glass factory near Warsaw. In his attempts to make artificial rocks, Dr. Morosewicz accidentally produced some more or less crystalline masses extremely rich in corundum and spinelle. This led him to determine the chemical conditions under which these minerals had been formed.

He isolated and analysed them, and also ascertained the composition of the mass which remained after they had separated out, for they always belonged to the first period of consolidation. He found that the ratio of the alumina-silicate bases (K_2O, Na_2O, CaO) to the alumina, in what may be called the mother-liquor, was very nearly 1:1. This is the ratio characteristic of the felspar group, and the fact naturally suggested the conclusion that, when alumina is present in excess of that given by this ratio, it is liable to crystallise out in the form of corundum alone, of corundum and spinelle, or of spinelle alone; the amount of spinelle being determined by the amount of magnesia present.

He then proceeded to verify this conclusion by dissolving alumina in artificial magmas corresponding to anorthite, nepheline, albite, orthoclase, and to mixtures of these. The results were completely in accordance with theory, except that a pure orthoclase-magma was found, to his astonishment, to possess little or no power of dissolving alumina. But this was not all. One or two additional facts of great interest revealed themselves during the progress of the research.

Alumina, in the form of bauxite, was found to be soluble in different proportions in the different magmas. Thus, in one case, two mixtures were prepared; one corresponding approximately to anorthite with two per cent. of soda, another to nepheline with one and a half per cent. of lime. To 212lbs. of the first, 50lbs. of

bauxite were added, and to the same amount of the second, 5 grams of the same substance. In four hours the nepheline mixture melted to a homogenous mass in the hottest part of the furnace (about 1,300 deg. C.), but after twenty-four hours the anorthite mixture, under the same conditions, was imperfectly fused, a considerable amount of alumina remaining undissolved. After cooling it was found that the nepheline mixture was crowded with microlites and minute crystals of corundum and nepheline, and that the anorthite mixture contained cavities in which beautiful glistening crystals of corundum were associated with unmelted grains of alumina. The nepheline mixture contained 29·5 per cent. of corundum, whilst the anorthite mixture contained only 5 per cent. Thus, under similar conditions as to temperature, alumina is six times more soluble in a nepheline-magma than in an anorthite-magma.

The experiments with the albite-magma were exceptionally interesting, for in addition to corundum, needles of sillimanite were obtained, and as these sometimes pierced the corundums it was clear that they had formed first. Now, in albite (Na_2O, Al_2O_3, $6SiO_2$) the ratio of soda to alumina to silica is 1 : 1 : 6. The formation of sillimanite might therefore be reasonably expected to occur if there were an excess of silica as well as alumina above that given by this ratio. Further experiments proved that this is the correct explanation. Sillimanite could easily be produced by making a magma in which both alumina and silica were in excess of that given by the ratio 1 : 1 : 6.

Here then we have a clear demonstration of the conditions under which corundum and sillimanite may form in igneous magmas. Spinelle and cordierite come under the same law. Both require the presence of magnesia, and cordierite requires also an excess of silica above that necessary to form felspar with the soda, potash and lime present. Twenty-five grammes of a mixture corresponding to pure spinelle (MgO, Al_2O_3) were added to a mixture corresponding to albite. The cooled mass was found to be crowded with microlites of spinelle. Plates of corundum and prisms of sillimanite were also formed near the wall of the crucible, but not in the centre of the mass.

Cordierite was formed in a magma of andesitic character in which the ratio of the felspathic bases to alumina to silica was 1 : 1·25 : 7 and in which 5 per cent. of magnesia was present. The cooled mass consisted of idiomorphic crystals of cordierite, octahedra of spinelle, prisms of labradorite, and microlites of augite in a glassy base. It bore the closest resemblance to a cordierite-vitrophyrite from the Orange Free State described by Molengraaf, and to the allied rocks from the south-east of Spain to which I have already referred.

Dr. Morosewicz summarises his results as follows:

In supersaturated alumina-silicate-magmas whose general com-

position is $MeO, mAl_2O_3, nSiO_2$ ($Me = K_2, Na_2, Ca$; $n \geq 2$), the whole of the excess of alumina $(m-1)$ separates out: (a) as corundum if no magnesia or ferrous iron be present, and if n be < 6; (b) as sillimanite or sillimanite and corundum if n be > 6. When the magmas are rich in magnesia the excess of alumina separates out (c) as spinelle or spinelle and corundum if n be < 6; and (d) as cordierite or cordierite and one or more of the other minerals if n be > 6.

The experiments of Dr. Morosewicz give a very complete and satisfactory account of the conditions under which corundum forms in felspathic magmas. But the mineral is found also in non-felspathic rocks, such as the dunite of North Carolina, where, according to Dr. Pratt [16], it has crystallised out of a dunite-magma.

Now, in his experiments with basic magmas containing magnesia, Morosewicz found that silicates of magnesia were rare or absent in those masses which contained corundum. Almost the whole of the magnesia combined with alumina to form spinelle, and it was only when there was a deficiency of magnesia that corundum was produced. Moreover, in magmas with an excess of silica over that necessary to form felspar, cordierite was produced. How then can alumina crystallise out of a highly magnesian silicate-magma? Why are not spinelle and cordierite formed instead?

I cannot answer these questions. Will someone who has the necessary means at his disposal experiment on the solubility of bauxite in a peridotic magma? If Pratt's theory of the origin of the North Carolina corundum be correct, alumina should be soluble and should separate out as corundum.

In the preceding sketch of the natural history of corundum, spinelle, sillimanite, and cordierite, I have by no means exhausted the subject. I have merely called attention to a number of well-established facts which throw a considerable amount of light on the mode of origin of these interesting minerals. It is clear that they may be formed by the crystallisation of sedimentary deposits under the conditions which prevail in the deeper portions of the earth's crust, and that they may also crystallise out of molten magmas. They serve therefore as a bond of union between igneous and sedimentary rocks. The cordierite-bearing contact-rocks have certainly never been in a state of igneous fusion; and yet there has been a sufficient amount of molecular freedom to admit of groupings of the same type as those occurring in molten magmas.

To what extent can these minerals be regarded as the products of normal igneous magmas? In many cases where they occur as authigenic constituents, they have undoubtedly crystallised from a magma which has been modified by the absorption of foreign material. Indeed, so frequently is this the

case, that the very existence of normal magmas capable of forming corundum, cordierite, and sillimanite is, I think, open to question. But, however this may be, there can be no doubt that such magmas are local and exceptional.

How does this fact bear on the question of the absorption of sediments by igneous rocks? In clays, shales, and slates there is a large excess of alumina over that required to form felspar with the alkalis and lime present. Thus in a Coal Measure clay from Fifeshire recently analysed by Dr. Pollard, the molecular ratio of the alkalies and lime to alumina is 1 : 4·31 ; in two slates from the Ardennes, analysed by Prof. Renard, it is 1 : 5·8 and 1 : 5·5 respectively. If such rocks were absorbed by granite on an extensive scale, would not sillimanite and cordierite be far more common than they actually are? At first sight one is inclined to answer this question unhesitatingly in the affirmative; but caution is necessary, for under plutonic conditions micas may form instead of them.

Thus, I have noticed, where biotite-gneisses have been used in the construction of vitrified forts in Scotland, that the biotite is often represented by a brown glass containing beautiful little octahedra of spinelle, and Vernadsky has shown that the fusion of muscovite gives rise to the formation of sillimanite and corundum.

Now if the water in biotite be reckoned as a base along with potash the ratio of $(K_2, H_2)O$ to Al_2O_3 is 1 : 1 as in the felspars, but in fused biotite after the water has been driven off it is 1 : 1·3, and the conditions necessary for the formation of spinelle exist. In fused muscovite the ratio is 1 : 3, and as there is no magnesia the conditions necessary for the formation of sillimanite and corundum exist. Thus the absence of the minerals in question from plutonic rocks cannot by itself be taken as evidence that no absorption of argillaceous sediment has taken place. Nevertheless, I think that when the distribution and quantitative relations of the micas to the other constituents are taken into consideration, there is good evidence, quite apart from the field relations, that granite masses, such as those of Cornwall, the south of Scotland, and the newer granites of the Highlands of Scotland, have not absorbed or dissolved any appreciable amount of argillaceous material. When we come to the older granites and the associated gneisses of the Highlands, which, as Mr. Barrow has shown, are so intimately connected with intense and widespread metamorphism, the case may be different. The extraordinary abundance of micas in some varieties may very possibly represent in part sedimentary material which has taken this form instead of giving rise to corundum, spinelle, sillimanite, or cordierite as it might have done if the water had escaped.

But the full discussion of this question would carry us too far, and I must conclude by expressing the hope that I have succeeded

in proving that great interest attaches to the study of minerals from all points of view, and that it is only by combining the results of geological, mineralogical, and chemical research that their natural history, in the proper sense of the term, can be made out.

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THE DRAINAGE OF CUESTAS.

By Professor W. M. DAVIS, of Harvard University.

(*Read May 5th, 1899.*)

YOUNG coastal plains present an even slope from the base of a hilly background of older land to their simple shore line. Rivers that are extended across such plains, following a course that is consequent on the slope of the surface, dissect them transversely, opening shallow valleys between strips of low uplands. The latter may be called "do-abs" (more explicitly, young coastal plain doabs), or two-river spaces, by a slight extension in the meaning of the word as used on the great fluviatile plain of northern India, where it applies to the pointed area of land that lies between the two forks of a river. As time passes and lateral drainage is developed on either side of the main consequent streams, ravines are gnawed in the margins of the doabs, and they thus come to be fringed with many branching spurs; they may then be called fringed doabs. Still later, little trace of the continuous upland surface will remain, so completely have the lateral valleys been developed; the interfluviatile strips may then be called maturely-dissected doabs.* Thus a series of systematically developed forms may be sketched out and matched with actual examples at nearly every step.

With greater regional elevation the coastal plain becomes broader, and older strata are reached when the valleys reveal the basal members of the stratified series. So long as the strata are of essentially uniform resistance to the weather, or so long as the more resistant strata are at the bottom, and the less resistant are at the top, no significant variation from the doab type appears. But when weak basal layers are covered by distinctly stronger layers in the middle or upper part of the series, the transverse relief of the doabs may give place to a longitudinal relief of quite another appearance. The weak under layers soon undermine their thin cover along the inner part of the plain, and waste away close to baselevel, forming an inner lowland. The resistant layers still retain a significant relief, with a rapid descent across their outcropping edge to the inner lowland, and a long gentle slope to the coastal lowland. The valleys of the extended consequent rivers are relatively narrow where bordered by the resistant layers of the upland. Chunnenugga ridge in Alabama is a good example of a longitudinal upland of this kind; the inner lowland is known as the Black Prairie from the colour of its rich soil, and here are

* Objection may be made by observers living in the Punjab to the extension in the meaning of doab here proposed, on the ground that only the original meaning of the term should be employed. But such an objection goes too far, for the original meaning of the term is simply the confluence of two rivers, and it is only as a secondary meaning that the space between two confluent rivers is understood. Etymologically, the term applies also to the space between two associated rivers that are not confluent, and when thus used it is not further from its original meaning than delta is; for some deltas are not triangular in outline. It should be understood that a two-syllable sound should be given: *do-ab*.

the chief cotton plantations and several of the larger cities of the state; the outer lowland is called the Coastal Prairie. The "ridge" itself is a broad upland, much dissected by small valleys, and nowhere presenting the narrow crest-line which the term ridge ordinarily suggests. A good view is obtained across the inner lowland from the spurs on the inner slope of the upland; the outer slope is so gentle that its inclination is hardly noticeable. Such an upland may be called a "cuesta." Coastal plains having their upland and lowlands thus arranged in longitudinal belts may be called "belted coastal plains."

It is not uncommon to find Mesozoic or Palæozoic strata still standing in such a relation to an older land-mass as to suggest that, when first lifted from the ancient seas, they formed the basal strata of coastal plains, whose subsequent history revealed a succession of doabs or cuestas, according to their structure. After the greater or less obliteration of their earlier relief, regional elevation may have called forth a new series of forms. The forms seen to-day are members of the n^{th} series in such a succession. In consequence of the greater chance of induration in the strata of ancient than of modern costal plains, cuestas predominate among the reliefs of the former, and doabs among those of the latter. The Oolite and Chalk cuestas of the Mesozoic coastal plain of eastern England, and the Niagara and Devonian or Carboniferous cuestas of the Palæozoic coastal plain of the northern United States may be cited as examples having well-defined longitudinal relief. There may also be an imitation of the structure of coastal plains, where uplift places masses of ancient rocks in appropriate relation with gently-inclined strata of later date. For example, the ancient rocks of the Odenwald and Schwarzwald imitate the older land, with regard to which the Triassic and Jurassic strata on the east and south-east stand in the relation of a coastal plain series; and a superb cuesta, whose strongest relief is known as the Schwäbische Alb, is determined by the heavy Jurassic limestones. A beautiful series of cuestas is found in France, eastward from Paris; the Vosges here represent the older land, while five or six resistant strata, alternating with weaker strata, from Jurassic to early Tertiary in date, form cuestas of greater or less strength and continuity. These are well described in De Lapparent's "Leçons de Géographie Physique."

A few words as to the term *cuesta*. Anyone who will revise the examples mentioned above will find a distinct repetition of physical features in them all. The upland is always formed on the more resistant layers, with a stronger slope on the outcrop side toward the older land and a gentler slope on the dip side; yet no indication of this unity of characteristics is to be found in the names by which these forms are known. If physical geography is to advance, the recognition of recurrent features must be indicated by naming them as a class. Finding no name in use for

the forms here considered, I have, after waiting several years in hopes of finding a satisfactory word, advocated the general adoption of the term cuesta, and for the following reasons: Cuesta is a Spanish word, meaning hill or slope. The term is actually employed for forms resembling those here described in New Mexico, as is stated by Hill in an important article on "Descriptive Topographic Terms of Spanish America" (*Nat. Geogr. Mag.*, vol. vii, 1896, pp. 291-302); or, to be more precise, cuesta is the name of the upland and the long, gentle slope of such forms. By the same natural extension of the original meaning that makes mesa apply to the whole of a tabular elevation, instead of only to its upper surface, cuesta may be made to apply to the entire body of the unsymmetrical linear elevation that is characteristic of certain denuded coastal plains. There may be objection to this use of the word, but, until a better name is suggested, cuesta will serve a useful purpose.

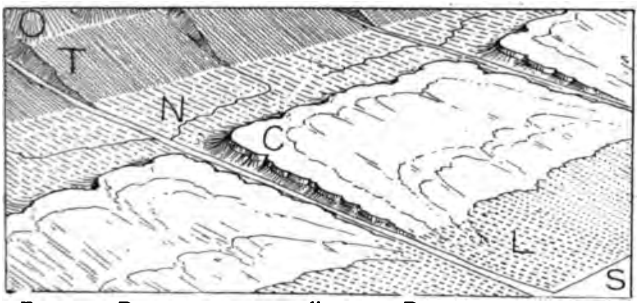

FIG. 1.—DIAGRAM OF A CUESTA, DEVELOPED BY THE MATURE DENUDATION OF A COASTAL PLAIN.

The morphology of a cuesta is so systematic that definite names arise very naturally for its several parts. Its upland descends by a gentle outlooking slope to the outer lowland L, (Fig. 1), and by a stronger infacing slope or inface to the inner lowland N, beyond which is the stripped belt T, and the older land O. If the inface is strong and steep it is called an escarpment; but this term, which applies as well to the rimming cliffs of a mesa, cannot be advisedly applied to the entire body of a cuesta, although such is the usage of some English writers. Escarpment is already so well defined and so useful in its proper sense, that it should not be made to include the outlooking slope of a cuesta, which has nothing like an escarpment in its nature. If the strata of a typical cuesta have a dip of five or ten degrees, then a change to a gentler dip causes a greater irregularity in the outline of the inface, until the cuesta becomes a mesa; while a change to a stronger dip produces a sharper and more rectilinear crest and a greater approach to symmetry in the lateral slopes,

until the cuesta becomes a ridge as in Fig. 2; or, as Hill puts it, "a cuesta is, in a manner, a transitional feature between a mesa and a mountain."

The drainage of a cuesta on a modern or a mediæval coastal plain gives an interesting illustration of the spontaneous rearrangement of the initial consequent streams by the subsequent growth of longitudinal streams in the area of the inner lowland. The diversion of the upper waters of the smaller consequents to become tributary to the larger ones, and the dwindling of the lower courses of the beheaded streams have been described in my "Notes on the Development of Certain English Rivers" (*The Geographical Journal*, vol. v, 1895, pp. 127-146). A very symmetrical example of changes of this kind is described in the course of an article on "The Seine, the Meuse, and the Moselle" (*Nat. Geogr. Mag.*, vol. vii, 1896, pp. 189-202, and *Annales de Géogr.*, vol. v, 1896, pp. 25-49). In more ancient coastal plains, the longitudinal subsequent streams, following the lowlands of weaker strata, become more and more important; and what with unequal movements of elevation and depression, the discharge of these streams is not always to be found down the dip of the strata in the direction of the initial consequent master streams, but it may come to be at one or the other end of the lowland, as is the case with the Severn* and the St. Lawrence. Yet on all

FIG. 2.—DIAGRAM OF A CUESTA AS A TRANSITIONAL FORM BETWEEN A MESA AND A RIDGE.

* Various examples might be given to show that the origin here suggested for the longitudinal streams of the lowlands of belted coastal plains is not always recognised. For example, Prestwich thought it possible that the Thames once ran north-east from Oxford to Cambridge along the lowland that is determined by the weak Oxford clays, and that its passage through the Chiltern hills (Chalk) by the gap at Goring was the result of a later diversion (*Quart. Journ. Geol. Soc.*, vol. xlvi, 1890, p. 177). Dr. Gregory does not accept this view, but suggests that the Avon and the Trent, which follow the lowland determined by the weak Lias or Trias strata inside of the Oolite escarpment, may be consequent upon a general uplift of central England, with greatest height near Rugby, and radial slopes thence outwards in all directions (*Natural Science*, vol. v, 1894, p. 106). The difficulty in such explanations is that they do not take sufficient account of the arrangement that the river systems would acquire during the denudation that preceded the date at which the explanations begin. The original extension of the Mesozoic formations of central England was once much greater than it now is. During the great denudation from the original to the existing extension of these formations, there must have been opportunity for much adjustment of streams to structures, as described in the *Geographical Journal*, above referred to. It does not seem admissible to leave all these possibilities out of consideration, and to assume one or another course for a river, without regard to the previous history of its basin.

cuestas the residual consequent streams are losing drainage area, and the opposite or obsequent streams are gaining, as the inface wastes and retreats in the direction of the dip. This brings me to the most interesting point in the evolution of cuestas; namely, the signs of progressive changes now and recently in operation, in illustration of which I wish to describe certain special features observed in the strong cuesta of the Swabian Alp of Wurttemberg in 1894, and on the smaller cuesta of the Cotteswold Hills of England in 1894 and 1898.

The general features of the first example are shown on the *Geognostische Uebersichtskarte* (1894) and the *Gewasser und Hohenkarte* (1893), issued by the Königliche Württembergische Statistische Landesamt. Topographic details may be found on the sheets of the *Karte des Deutschen Reiches* (1 : 100,000), as far as issued. A general section through Stuttgart exhibits a typical succession of forms, as in Fig. 3. The heavy limestones

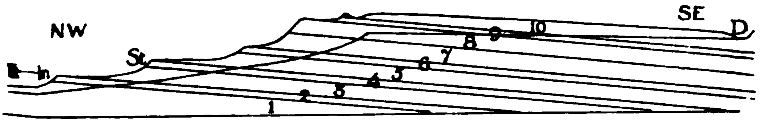

FIG. 3.—SECTION OF THE SWABIAN ALB, FROM HEILBRONN TO THE DANUBE, LOOKING NORTH-EAST.

of the White Jura form the chief cuesta, whose general name hereabouts is the Schwäbische Alb (sometimes "Alp,") with various local names, as Rauhe Alp, Heuberg, etc. Two members of this limestone, 8 and 10 (Fig 3), and a weaker intermediate layer, 9, determine a doubling of the upland crest; the lower member, an even bedded limestone, forms the chief promontories and cliffs of the infacing escarpment; the upper member, of more irregular structure, covers the outlooking slope; it advances towards the escarpment and fades away on the upland in spurs and hills, beyond which a flat platform leads forward to the main cliffs. The stronger member of the Brown Jura, 6, makes a bench near the base of the infacing slope. The Black Jura, 4, makes a subordinate cuesta in the neighbourhood of Stuttgart (Scharwald, Welzheimwald), and the Keuper (Upper Trias, 2), makes another near Heilbronn (Lowensteinberg, Heuschelberg, Stromberg). These subordinate cuestas are much dissected by small valleys.

It is evident from the above section that all the strata there represented once had a greater extension to the north-west, and that they will in the future be worn back further to the south-east. The strong limestones of the White Jura must generally form the chief divide during these changes. This divide must retreat to the south-east, because of the arrangement of strong and weak strata.

Hence the consequent streams on the high ground of the out-looking slope will be more and more shortened or beheaded, while the obsequents on the lower ground beneath the infacing escarpment will be lengthened. Thus the Danube's loss is the Neckar's gain. The cuesta should to-day exhibit, in different parts of its length, various signs of these progressive changes. If ST (Fig. 4), represents an early stage of a consequent stream with its branches, and B represents the present position of the divide on the cuesta crest, then the main stream will normally be found heading at K in much diminished volume, while the small lateral stream J will not yet be affected. The larger ST was in the beginning, the deeper will be the notch in which its beheaded remnant lies; and through these deeper notches the chief roads and the railroads will be laid, thus recalling the reason for the location of certain passes over the inner range of the Himalaya to the plateau of Tibet, as explained by Oldham (*Geographical Journal*, vol. iii, 1894, p. 169).

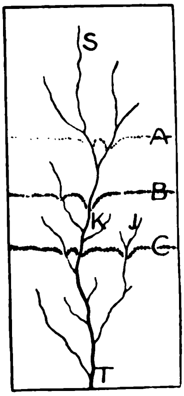

FIG. 4.—DIAGRAM OF THE RELATION BETWEEN CONSEQUENT STREAMS AND CUESTAS.

A whole series of deducible features of this kind is to be seen near Ebingen, where the Schmiecha is the beheaded consequent and the Eilach is the encroaching obsequent. If one ascends the Schmiecha from the Danube, the stream is manifestly too small for its valley, for while the valley swings in strong curves, the stream wanders in small, irregular curves on the valley floor. At Kaiseringen (Fig. 5) the valley has a well-defined meander to the west, and a narrow-necked spur enters the meander from the north-east to south-west. Where the valley walls are concave they are steep and wooded; where convex, they have a gentle slope, and are generally cleared and cultivated. Nothing less than the centrifugal force of a large stream seems competent to originate a valley of so highly specialised a form. The valley of a small stream may, in time, become wide, but it can never acquire the peculiar curvature and form appropriate to the valley of a large stream. The deeply incised meanders of the Wye illustrate the typical relation of accordant curvature in stream and valley. No less impressive are the meanders of the north branch

FIG. 5.—BIRD'S-EYE DIAGRAM OF THE SCHMIECHA AT KAISERINGEN, LOOKING NORTH.

of the Susquehanna in the Allegheny plateau of northern Pennsylvania. The beautiful serpentines of the valley of the Seine in the Chalk plateau of Normandy above and below Rouen again illustrate the normal proportion between product and agent. The swinging valley of the Moselle below Berncastel teaches the same lesson, only to be re-enforced by that of the Neckar between Heilbronn and Heidelberg. After seeing these repeated examples of accordance between stream and valley, the discordance between the Schmiecha and its broad-floored, meandering trough is very striking. It recalls the striking discordance between the minute irregularities of the Bar, a tributary of the Meuse in northern France, and the sweeping curves of its meandering valley, a discordance that is demonstrably the result of the loss of the former upper waters of the Bar (now called the Aire) by diversion to the Aisne (De Lapparent, *Annales de Géogr.*, vol. vi, 1897, p. 79).

Passing further toward the north-west, the disproportion of the Schmiecha and its valley becomes excessive at Ebingen, where the

FIG. 6.—SKETCH OF THE VALLEY OF THE SCHMIECHA FROM THE SCHLOSSENFELSEN NEAR EBINGEN, LOOKING SOUTH-EAST.

landscape may be finely observed in bird's-eye view from a tower on the Schlossenfelsen (S, Fig. 7), on the verge of the upland east of the town. The high and steep walls of the valley on the south, cut chiefly in the firm limestone of the uplands, descend to the flat grassy meadows of the valley floor, where the little stream wanders about in haphazard fashion, as in Fig. 6. Here, as well as further down stream, the valley floor has the appearance of being aggraded, or built up with stream-borne waste, for it seems to lap upon the base of the side slopes. At Ebingen (E, Fig. 7) a flat-floored side valley comes in from the north-east, and as more water comes from the stream in this side valley than from the continuation of the main valley, the former is regarded as the "head" of the Schmiecha. Both the side and the main valley here increase somewhat in width, probably because the upper limestone is thinning out and the weaker layers next beneath therefore exert a greater control over the valley forms. The main valley from

Ebingen to the divide, about two miles distant, is almost or quite dry, and in the absence of a stream the waste from the walls encroaches upon the floor, giving its cross section a catenary curve. Little fans of rock-waste are spread forward at the base of small ravines that descend from the uplands, and between some of these fans the valley floor is somewhat marshy; but in general its surface is occupied by patch-work fields. The valley walls are continued for several miles further on, and for perhaps a tenth of that distance vestiges of the Schmiecha floor are seen as benches at appropriate altitude on the side slopes; but on passing the well-defined divide the valley bottom descends rapidly to the north-west, and the Eilach, fed by several side valleys, soon becomes a rushing stream of direct course between slopes that unite in distinct V-form at the stream line.

The contrast in the form of the valleys on either side of the divide is very striking. On the south-east the highway runs on a straight line, and with a very gentle ascent, from Ebingen to the divide; then it turns to right and left to lessen the slope on the descent to Lautlingen (L, Fig. 7). Going on to Lauffen (F), it finds no flat valley floor, but has to bench its way along the valley-

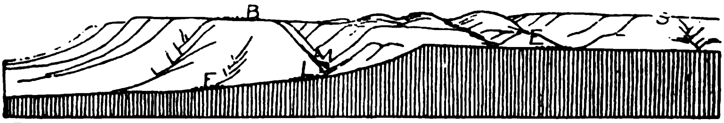

FIG. 7.—SECTION OF THE SWABIAN ALB AT THE DIVIDE BETWEEN THE EILACH AND THE SCHMIECHA, LOOKING NORTH-EAST.

side that descends to the sharp-cut stream line. Lauffen is not spread out on a plain, like much of Ebingen, but perches on a slope. Looking back to the divide, it has the appearance of an even wall across the valley-head, as in Fig. 8. The valleys of the side streams are no longer flat-floored, like that of the branch that enters the Schmiecha valley at Ebingen, but are sharply incised. One comes from the north-east at Lautlingen, and the village of Margarethen (M, Fig. 7) is almost hidden in the trench that has been cut beneath the former floor. A wet-weather stream that has very recently been diverted from the Schmiecha to the Eilach is just beginning to deepen its course. The railway that found an easy path in the valley of the Schmiecha, with low bridges of light construction across incoming side-streams, begins its north-west descent by cutting into the valley-floor a quarter-mile before reaching the divide; then, descending rapidly, it soon has to build a high viaduct in crossing a deep-cut stream from the south-west. The names, Eilach and Lauffen, appear to be derived from the activity of this obsequent stream.

The valley of the Eilach rapidly widens as the limestone thins on the upland, and as more and more of the weaker strata of the

inface appear on its slopes. The escarpment is reached a little beyond Lauffen, and then follows the open country of the upper Neckar, with its low cuestas, as shown in Fig. 3. A fine view of all these features north-west of the divide may be had from the Horn, a sharp promontory west of Lauffen, reached by a path that ascends along the wooded slope. The upland on the north-east side of the valley is seen in profile, with the village of Burgfelden (B, Fig. 7) on the edge of its even platform overlooking the Eilach valley. It seemed to me that the story of Jack and the Beanstalk might well have originated in the lower villages amid such surroundings.

A few miles north-east of the Schmiecha and the Eilach come the Lauchert and the Starzel, repeating item by item all the features above described. As before, the Lauchert wanders about aimlessly on a flat valley floor, at one place flowing a hundred

FIG. 8.—VIEW OF THE DIVIDE BETWEEN THE EILACH AND THE SCHMIECHA, LOOKING SOUTH-EAST. (LAUTLINGEN IS JUST BELOW THE EVEN FLOOR OF THE DIVIDE.)

yards directly "up stream," while the valley follows sweeping curves, with stronger and gentler slopes on its concave and convex walls. As before, the disproportion between valley and stream increases in passing towards its head. At Neufra, the stream is already very small; at Burladingen, it is nearly lost, and with its disappearance the steep walls and flat floor of the valley are replaced by a blending of wall and floor in catenary curve. The grassy meadows are at last replaced by cultivated fields, stretching across the floor from side to side, and interrupted only when the surface becomes marshy between faintly convex fans. Then comes the sudden descent to the head of the Starzel at Hausen, with the sharp-cut valleys of the lateral streams that have been diverted from a higher to a lower discharge; and a little further on the promontories of the escarpment stand forth overlooking the lowland. The famous castle of Hohenzollern caps an outlier a little to the west.

The only novel feature in this second example is the occurrence of a large branch valley coming in from the north

just below Neufra, and heading in the plateau, like J, Fig. 4. I was not able to follow this valley to its source, but as represented on the large-scale topographic maps it does not seem to have been beheaded. Nevertheless, the stream and valley here exhibit something of the discordance already described, thus suggesting either a beheading not recognisable on the maps, or a decrease of stream volume due to climatic change. The latter alternative will be more fully considered further on.

Whatever the origin of the discordance between branch stream and branch valley, there can be no doubt as to the chief cause of the much greater discordance between main stream and main valley. By ascending the slope alongside of the watershed in the valley floor, the contrasted action of the two headwaters is presented in the clearest manner. So impressed may one become with the reality of the southward migration of the divide and of the northward diversion of lateral tributaries, one after the other, that it is difficult to restrain the imagination from figuring an active advance of the process, and to maintain a conception of the extreme deliberation with which the whole series of changes advances. One comes unconsciously to feel that, if he should return to the same spot a few years later, a visible progress would have been made in the wasting of the steeper north-western slope, and the divide would be found to occupy a position appreciably further to the south-east. Yet, on considering the extreme slowness of the process, it is manifest that centuries must pass before the Wasserscheidekreuz by the roadside need be moved. The extreme disproportion between historical and terrestrial time is seldom more convincingly emphasized. Nevertheless, it is a pleasing experience to allow the mind to forget the years and centuries of human history, to let it drift into sympathy with the march of events that has developed the existing form of the Alb, and thus to realise that the march has not yet halted. When this sympathetic mental attitude is gained, as it is so easily from such a point of view as is presented on the slopes above the divide, one sees how little appreciation of physical geography has been reached by those who contend that the analysis of a landscape detracts from the enjoyment of its beauty. The truth is that the finest beauties of the scene, the harmonious relations of its parts, are not perceived until the analysis is made. So long as analysis is distasteful and laborious, it must interfere as much with one's enjoyment as the necessity of frequent resort to a dictionary interferes with the enjoyment of classic authors; but when the analysis of a landscape comes to be like reading a foreign language at sight, its exercise is not a tiresome effort, but a stimulating pleasure, and it then adds as much to the meaning and interest of scenery as the recognition of the true relation of construction and ornament adds to the appreciation of a well-proportioned Gothic cathedral in the mind of one who is versed in the history of art

and architecture. Many a traveller has crossed the Swabian Alb by one or another of its beheaded valley passes; the slopes of the valley side may have attracted the traveller's attention by reason of their graceful descent to the meadow-like floor; but his enjoyment of the passing view must have fallen as far short of its full measure as would that of an untaught sightseer on looking at an allegorical fresco while knowing nothing of the allegory or of its suggestive history.

There are several other examples of beheaded streams further north-east, but as my acquaintance with them is at present gained chiefly from the study of maps, they need not be further described here. Brief mention may, however, be made of the maintenance of headwaters for a number of miles inside (north-west) of the escarpment by the Wörnitz and the Altmühl, apparently because these streams lie about midway between the Neckar and the Main, where the capturing obsequents have not yet reached them.

There is one element in the problem that may seem to stand against the explanation here offered. The valleys of the beheaded Schmiecha and Lauchert still retain clear impress of the form given them when their streams were much larger; they have not since then been much changed by weathering. And yet the process of beheading, by which these streams have been reduced from an appropriate to an inappropriate volume, involves a considerable southward migration of the divide in consequence of the effective action of the weather on the north-western slope. It therefore seems like blowing hot and cold in the same breath to accept only a small change in one place and a much greater change in another. This seeming contradiction is lessened by two considerations. In the first place, the widening of the beheaded consequent valleys is retarded by the resistance of the strong limestones in which they are cut, while the southward migration of the divide must have been accelerated by the rapid wasting of the weak strata that now occupy the floor of the inner lowland. Even if the strong White Jura limestones overlay the weaker layers, the latter would rapidly undermine the former as soon as deep valleys were cut through both. But, in the second place, it is not necessary to assume that a great destruction of the stronger upper layers was accomplished while the beheading of

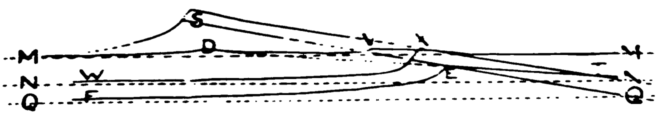

FIG. 9.—DIAGRAM OF A CUESTA IN TWO CYCLES OF DENUDATION.

the streams was in progress. Let it be postulated that MM, Fig. 9, was the effective baselevel of the region when it was first elevated so as to be denuded into lowlands and cuestas. During the

mature stage of this cycle of denudation the crest of the White Jura cuesta may have had some such position as S; but in the old age of the same cycle the cuesta-making strata would be reduced to faint relief at V, while some of the consequent streams might still retain their headwaters in the neighbourhood of D if the attacking obsequent streams did not have at that time sufficient advantage to push the divide further south-east. The Schmiecha and the Lauchert might then have had headwaters on the weaker strata from D nearly to V; they would thus have resembled the existing condition of the Wörnitz and Altmühl, as stated above. Now, in consequence of a new uplift, by which the baselevel takes the position NN, let each revived consequent stream cut a narrow valley, DET, before it is significantly beheaded; and a graded slope then being reached, so that further valley deepening almost ceases, let the obsequents push the divide from D to X, thus reducing the consequents to about their present small volume. It is possible that still another uplift changes the baselevel from NN to QQ, for the Neckar to-day occupies a narrow valley for much of its length, incised beneath a broadly-denuded surface; thus the obsequent profiles would be changed from XW to EF, which imitates the present condition satisfactorily. Under these suppositions only a small part of the strong White Jura limestone was consumed while the consequents were shortened from a length of DT to ET, and even the part thus consumed was worn back chiefly by the undermining of the weaker layers of the lower infacing slope. Guided by such suppositions as these, it is not unreasonable to suppose that the consequent valleys in the hard limestone still retain much of the form given to them before their streams were greatly diminished by beheading.

Whether the postulates here introduced as to successive baselevels, M, N, and Q, are correct, can only be determined by the study of a large area; but as far as I have read there is nothing to contradict them. Whether the postulates aid or encumber the explanation is, perhaps, a matter of taste and temperament, varying with the degree of confidence felt in the various general onsiderations previously introduced.*

* Reference may here be made to the importance of the consideration of baselevels and cycles of denudation in explaining certain problems of American geomorphology. Lesley expressed surprise at the small amount of erosion accomplished on the low anticline, A (Fig. 10A), in the Allegheny plateau, while an immense amount of erosion had been accomplished on the huge anticline, B, of the neighbouring Allegheny mountains, both rock-arches having been exposed to denudation for the same periods of time (*Second Geol. Surv. Penn.*, vol. x.). But when it is recognised that the region concerned stood for a long time in a lower position, with the baselevel MM, and that only during

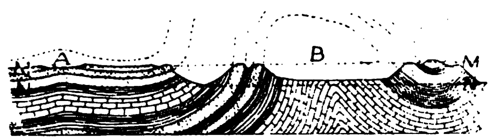

FIG. 10A.—SECTION OF THE ALLEGHENY PLATEAU AND RIDGES IN CENTRAL PENNSYLVANIA.

Turning now to the cuesta known as the Cotteswold Hills, formed on the resistant Oolitic strata of the Mesozoic coastal plain of England, let me first refer to an article by Mr. Osborne White, "On the origin of the High-Level Gravel with Triassic débris adjoining the Valley of the Upper Thames" (*Proc. Geol. Assoc.*, vol. xv, 1897, pp. 157-174). It is there shown that abundant gravel deposits, derived from rocks in the valley of the Severn, occupy the valleys of the upper branches of the Thames in the Cotteswolds. These gravels and their source have long been known, and their distribution has heretofore been accounted for by marine and by glacial action; but Mr. Osborne White thinks that their best explanation is found in connection with the rearrangement of rivers appropriate to belted coastal plains. Thus an independent line of observation confirms the beheaded condition of the Thames system, and suggests that gravels from the Neckar basin should be looked for in the valleys of the beheaded branches of the Danube. I very much regret that the existence of these Cotteswold gravels was not known to me at the time of preparing my "Notes on the Development of certain English Rivers," in 1894, but perhaps the fact of writing during an active tour across France may excuse the oversight of so important a matter.*

Mr. Osborne White states that with the diversion of the original headwaters of the Thames system to the Severn "the supply of débris from rocks of earlier age than the Lias, which they had hitherto furnished, came to an end. And the volume of water in these branch streams, and, therefore, also in the main or trunk stream, being greatly reduced, the width of the channels they were thereafter able to erode was correspondingly diminished" (*l.c.*, p. 171). This normal consequence of the development of a well-adjusted cuesta drainage was not examined in 1894 for lack of time; but during October, 1898, I made several excursions along the valleys of the Cherwell, Evenlode, Windrush, and Coln, with most interesting results. At the same time, the evidence of a

part of Tertiary time has the baselevel been at [illegible] the imagined difficulty disappears. Again, a comparatively recent date has been inferred for the fault of Pine Mountain, Kentucky, because the crest of the mountain, P (Fig. 10a), has retreated so little from the line of the fault by which the strata are there upturned (*Mem. Geol. Surv. Ky.*). But it is be postulated that for a long time after the date of the fault, MM was the local baselevel, and that the elevation of the new baselevel, NN, resulted from a late Tertiary uplift, then it is manifest that the date of the fault may be as ancient as that of the general Appalachian mountain folding. At the time when the above reports were written, baselevels and cycles were little considered.

FIG. 10.—SECTION OF PINE MOUNTAIN, KENTUCKY.

* Since the publication of my essay, I have learned of an article by [illegible] Ellis, "On some features in the formation of the Severn Valley" (*Trans. [illegible] Philosophical Society*, [illegible] 1882), in which he advocated a former continuation of the Severn south-eastward across the Cotteswolds, before the excavation of the longitudinal valley on the weak Liassic strata, by which the river now escapes to the south-west. So far as I know, this is the earliest suggestion of such a course for the river.

climatic change, already suggested on the Swabian Alb, here enters with greater strength, and thus adds a new complication to the problem. The one-inch maps of the Ordnance Survey (New Series), or, still better, the sheets of the coloured one-inch map, as far as published, exhibit most of the features recognised in the field. Bartholomew's reduction of the Ordnance Survey sheets suffice to indicate localities, but are on too small a scale to illustrate details of form.

The Cherwell seems to retain a greater share of its original length than any other of the Thames branches. It is in this respect, as well as in its relation to the encroaching streams of the inner lowland (Avon and Trent), a worthy fellow of the Wörnitz and the Altmühl. Between Banbury and Oxford there are many indications of diminished volume in the striking discordance between the minute irregularities of the stream and the swinging curvatures of its valley. The latter feature is not continuously displayed, but it is very striking at several points, notably between North Aston and Somerton, at Upper Heyford, and at Enslow. At the first and third of these localities, the stronger slope of the valley side is on the west, and presents a well-defined curve, concave to the east. At the second locality the stronger slope is on the east, with a curve concave to the west. These systematic forms, so characteristic of vigorous, able-bodied rivers, do not seem to be in any way producible by a little staggering stream like the Cherwell, which wanders about, as if bewildered, on the flat valley floor. The diversion of some of its waters to a canal should be noted, but even if this loss were made good the Cherwell would still be a small stream. Its headwater divide, at a height of about 400 feet, between Fenny Compton and Wormleighton, deserves closer examination than I was able to give it.

The headwaters of the Evenlode at Moreton-in-the-Marsh (417 ft.) lie on the broad floor of a wide valley. The gain in width here as compared to its lower course (as about Stonesfield) is due to its excavation in relatively weak Liassic strata, and hence no local signs of a meandering valley are to be expected at this point. The beds of quartzite and other midland gravels at Moreton are well known (see O. White, *l.c.*, pp. 160-162 In line with the present upper Evenlode, and a few miles farther north, there is a small stream known as Knee Brook. It first flows south from Hidcote Hill, near Chipping Campden, then east to join the obsequent Stour at Tidmington. The south-flowing part of Knee Brook therefore probably represents a former head of the Evenlode. Midland gravels are found on the hills that divide its source from north-flowing obsequent streams. Unlike the present Evenlode, Knee Brook occupies a relatively narrow and deep-set valley, over a hundred feet lower than the Moreton plain, and the valley sides descend close to the stream, leaving little space for a flood plain. Perhaps the name of this brook is

derived from its right-angle turn from south to east at the elbow of capture: certainly the analogy of "elbow" and "knee" is very suggestive. Whether the surname of Moreton had its origin in the marshy condition of the valley floor at the head of a beheaded river, or whether it is a corruption of March, might be determined by the local antiquarian.

Farther down the Evenlode, where its valley is eroded in the stronger layers of the Oolite, it is comparatively narrow and steep-sided. Between Stonesfield and Long Hanborough, it is as perfect an example of a meandering valley as one can wish to see. A beautiful succession of interlocking plateau spurs, six from the north and as many from the south, enter curves of very uniform dimensions. Each spur slopes gradually to its end, while the concave curve on the other side of the valley is steep, almost abrupt. Furthermore, the up-stream side of many of the spurs is somewhat cut away, and the steep slope of the concave curves is there prolonged nearly to the end of the spur; one spur north of Long Hanborough is reduced to a cusp, thus showing that a beginning had been made in the destruction of the spurs by the river that eroded the valley. A digression may be made in fuller explanation of this significant feature.

If a mature river, meandering freely on a broad valley floor in a region of moderate relief, is revived by the elevation of the region, it proceeds to carve a meandering valley. Its meander-belt (defined by a pair of sub-parallel lines, tangent to the meander curves on either side) is broadened as the valley is incised: hence the spurs descend with a gradual slope towards the abrupt slope of the concave walls, as in Fig. 11. The Moselle, below Berncastel in western Germany, and the north branch of the Susquehanna, for some distance below Towanda in northern Pennsylvania, exhibit these features with great distinctness. After a graded descent of the valley floor has been developed, deepening almost ceases, but widening continues. The up-stream side of the spurs is gradually worn away, apparently because the whole system of river curves moves bodily down stream. The spurs are at first sharpened (Fig. 12), then reduced to cusps (Fig. 13), and at last disappear entirely (Fig. 14), leaving a flood-plained valley floor on which the river meanders rather freely, with only occasional constraint from the valley walls as it swings against them here or there. Various stages in this systematic sequence of forms may be seen in the valleys of the Dordogne and the Lot, as these rivers flow westward from the central plateau of France across the belt of overlapping Mesozoic formations: a less advanced stage being

Fig. 11.—Diagram of a Narrow Meandering Valley, with Symmetrical Spurs.

found where the rocks are resistant, and a more advanced stage where they are weaker. The important point in the present connection is that the systematic trimming of the up-stream side of the Evenlode spurs gives new confirmation to the conclusion already reached regarding the origin of the meandering valley. It must have been eroded by a river that was large enough to swing in regular meanders accordant with the curving valley floor.

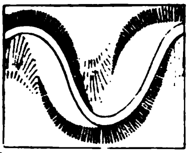

FIG. 12.—DIAGRAM OF A BROADENED MEANDERING VALLEY, WITH UNSYMMETRICAL SPURS.

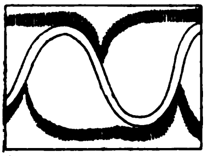

FIG. 13.—DIAGRAM OF A BROADENED VALLEY, WITH CUSP REMNANTS OF SPURS.

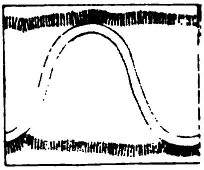

FIG. 14.—DIAGRAM OF A BROADENED VALLEY, WITH SMOOTHED SIDES.

Yet the Evenlode itself turns about aimlessly on the valley-floor. Instead of pressing closely against the steeper slopes, as the original river must have done while under-cutting them, it shows no such definite intention, but wanders here and there from side to side, and is about as likely to nip the gentle slope of a spur as any other part of the valley walls. A rapid glance at these features may be had from the line of the Great Western Railway, which, in the stretch above described, adopts a comparatively direct course, making cuts through the spurs and embankments across the valley-floor. The steeper slope of the up-stream side of the spurs is easily recognised from the unsymmetrical form of the cuttings. Even the one-inch maps indicate this detail of form with much fidelity.

The head of the Windrush was not within reach during the

FIG. 15.—SKETCH OF THE VALLEY OF THE WINDRUSH LOOKING WEST PAST CRAWLEY.

time at my disposal in the field, but between Burford and Witney its valley meanders with appropriate steep and gentle slopes, repeating the features just described for the Evenlode. One of the best curves is at the village of Crawley, where a fine sweep to the north is entered by a descending spur from the south, as in

Fig. 15; the steeper trimming of the up-stream side of the spur is very distinct. Other examples occur just below Osthall. The curving flood-plain, on which the stream idly loiters from side to side, is very probably somewhat aggraded, for, after loss of volume, the gradient of the valley-floor must have been insufficient for the needs of the diminished stream, and the waste washed in by side streams must have been soon deposited. In this case it would be natural that exotic pebbles should be found in wells beneath the alluvial floor. The change in the form of the valley sides, since the beheading of the rivers, has not been great, although the slopes are occasionally somewhat ravined.

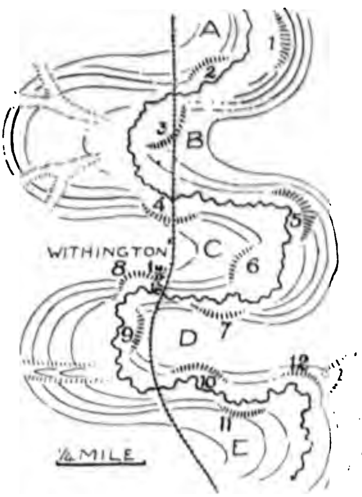

Fig. 16.—Diagram of the Valley of the Coln about Withington.

The Coln is in some respects the most interesting of the Thames branches, in the possession of a number of well-defined features suggestive of beheading. When visiting its upper course, I profited greatly from the company of Mr. S. S. Buckman, of Charlton Kings, who was already familiar with many of the best localities for observation. In the neighbourhood of Withington, the form of the Coln valley suggests a progressive diminution in the size of the river that has followed it. There are, first, large-scale meanders, indicated by the general form of the curving valley; second, much smaller meanders, indicated by concave nips or re-entrants at various points on the side slopes of the larger meanders; and, third, the minute contortions of the existing stream. Fig. 16 is a rough diagram, undoubtedly inaccurate in many details, but serving to represent the relation believed to exist among the several phases of the history here inferred. The spurs, lettered A to E, project into corresponding amphitheatre-like concavities, whose floor is above the present valley floor: thus the path of the original river at the time of its greatest volume is indicated. Successive concavities, numbered 1 to 12, are taken to represent indentations in the sides of the large meanders, caused by the river of medium volume; No. 5 is the most distinct of these. The existing stream of small volume flows irregularly on the valley floor. A careful survey of this locality with the object of making a detailed contour-line map is greatly to be desired. The top of

the spur south-east of the village may be recommended as a good point for a general view. The re-entrant curve marked 5 will surely take the observer's attention from the arrangement of the small fields or "allotments" upon its slope.

If the above interpretation of the valley form is correct, it might be inferred that the Coln was once formed by two good-sized forks, which united somewhere above Withington; and that the diversion of the western fork from the Thames to the Severn system caused the change from the large to the medium-sized meanders, while the subsequent diversion of the northern fork caused the change from the medium to the small existing meanders. This inference is well supported by the branching of the valley at Andoversford, a few miles north of Withington; one broad branch coming from the west, the other from the north.

Passing beyond the heads of these broad-floored valleys, one descends rapidly—in very good imitation of the examples on the Swabian Alb—by the sharp-cut obsequent valleys of the Chelt and the Isbourne to the inner lowland of the Severn-Avon valley. A railway follows the western branch and aids the encroachment of the Chelt by cutting and tunnelling through the divide, thus already diverting surface waters to the Severn system that would have otherwise remained faithful to the Thames for centuries to come. The broad meadow at the head of the northern branch falls off abruptly into the wedge-like valley of the Isbourne. The meadow is continued in benches a little north of the divide on either side of the valley, but the benches are actively encroached upon by slips in the weak Lias clays that underlie them. Just south of the divide, a side valley comes in from the north-west, flat-floored, as if aggraded; while to the north of the divide, a side valley comes in from the east, narrow and steep-sided even in the weak Lias.

According to the map in Mr. White's paper, some Triassic gravel has been found in the Coln valley, but it must be much rarer than in the valleys of the Windrush and Evenlode. There, the red quartzite is a conspicuous element in the soil of many valley-side fields, and in the construction of many roads; but two days of wandering in the Coln valley failed to discover a single quartzite pebble. In explanation of their absence, Mr. Buckman suggested that the upper branches of the Coln had not cut down through the Lias to the Trias at the time of their diversion to the Severn.

If the spontaneous rearrangements of drainage area here described were the only causes of change of volume in the streams, the branches of the Severn system ought to be as robust as those of the Thames system are feeble. To test this consequence of the theory, I visited the Stour in the neighbourhood of Shipston-on-Stour and Halford, and to my surprise found that stream also a misfit in a meandering valley, although not to so

striking a degree as in the examples above described. [illegible] to the map, the Avon is again a misfit [illegible] north of this district. A similar complication [illegible] found in the discordance between stream [illegible] in the case of the Meuse *above* the point where it has [illegible] and in the case of the Aisne *above* the point where [illegible] It is therefore evident that some other cause [illegible] divides must be concerned in these curious relations. [illegible] decrease of stream volume seems [illegible] changes due to diversion of tributaries from one river [illegible] to another. It has occurred to me that [illegible] may be due to increased evaporation following [illegible] ancient forests and the cultivation of the [illegible] the chief reason for decrease [illegible] change of external and obscure origin [illegible] problem I cannot now discuss further.

In spite of this climatic complication, it cannot be [illegible] by anyone who will examine the localities above described that considerable changes of drainage areas have been [illegible] the interaction of the streams themselves, and that these changes are of the kind outlined in the theoretical statement [illegible] of this essay. In view of the local evidence [illegible] former greater extension [illegible] north and north-west, it seems best not [illegible] original stream, as Dr. Gregory has [illegible] but to place it in the category [illegible] ment is the result of headward growth [illegible] thus making it an accordant member [illegible] appropriate to coastal plains [illegible]

While the explanation of local features [illegible] information from several converging lines of evidence, the general lesson deducible from the special examples [illegible] of even greater importance. The systematic [illegible] repeatedly found in the drainage of cuestas [illegible] systematic order of development and establish a well-defined class of [illegible] forms. Anyone who becomes persuaded [illegible] the general scheme by which this class [illegible] will find therein a new instrument of research. [illegible] naturally turn to look for the [illegible] on a cuesta as the untrained traveller [illegible] the streams. He will use his [illegible] advantage, by directing his steps at once to points where the most significant elements of form are expected, and [illegible] and concisely describe them as members of a well-known class. Thus fostered, systematic geography will gradually take the place of empirical geography, and the face of the earth will come to have new meaning to its inhabitants.

Cannes, February, 1899.

MAY, 1899.

ANNUAL GENERAL MEETING.

FEBRUARY 3RD, 1899.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

Messrs. R. Holland and A. C. Young were appointed Scrutineers of the ballot.

The following report of the Council for the year 1898 was then read:

THE numerical strength of the Association on the 31st of December, 1898, was as follows:—

Honorary Members	16
Ordinary Members—	
a. Life Members (Compounded)	156
b. Old Country Members (5s. Annual Subscription.)	7
c. Other Members (10s. Annual Subscription)	366
Total	545

During the year twenty-three new members were elected. The Council regrets that the Association has lost two members by death: Sir Robert Rawlinson and William Walker.

The income of the Association for 1898 from all sources was £239 18s 9d., and the expenditure was £249 8s. 1d. There was also a sum of £21 16s. 2d. due to the printers, against which may be set off £11 16s. 6d., the amount due for 1898, from the advertisement contractor. It will be seen that for the first time for several years the expenditure for the year has exceeded the income. This is due partly to the increased outlay on the library, foreshadowed in the report for 1897, and still more to the large amount required for printing the PROCEEDINGS. The money, however, has been well spent, for it is a long time since there has appeared in the PROCEEDINGS OF THE ASSOCIATION a paper of such great interest and value as Professor Lapworth's Sketch of the Geology of the Birmingham District. The slight falling off noticeable in the receipts is due to the fact that fewer new members were elected than in the previous year.

Five numbers of the PROCEEDINGS, consisting of 254 pages of text, 5 plates and 33 other illustrations, were issued during the year 1898. Thanks are due to the Authors for their contributions, and especially to Professors Lapworth and Watts for their "Sketch of the Geology of the Birmingham District," published in the August number. Your thanks are also due to Professor Watts for Plate XIII., published in the November number.

GEOLOGISTS' ASSOCIATION.

Dr. **Income and Expenditure for the Year ending Dec. 31st, [illegible]** **Cr.**

	£ s. d.		£ s. d.
To Balance from 189[illegible]	[illegible]	By Printing "Proceedings"	[illegible]
" Life Compositions	[illegible]	" " Monthly Circular	[illegible]
" Admission Fees	[illegible]	" Miscellaneous Printing	[illegible]
" Annual Subscriptions (less [illegible] returned)	[illegible]	" Illustrating "Proceedings" and [illegible]	[illegible]
" Dividends on Nottingham Corporation Stock	[illegible]	" Postages	[illegible]
" Sale of Publications	[illegible]	" Addressing	[illegible]
" Sale of "Record"	[illegible]	" Library (including [illegible] of St. Martin's Library)	[illegible]
" Sale of "Paris Basin"	[illegible]	" Attendance, Lighting, [illegible] Meetings	[illegible]
		" Furniture	[illegible]
		" Insurance	[illegible]
		" Stationery	[illegible]
		" Miscellaneous Expenses	[illegible]
		" Balance in Bank [illegible]	[illegible]
	£[illegible]		£[illegible]

Outstanding Assets and Liabilities, Dec. 31st, [illegible]

Assets.		Liabilities.	
Due from Advertisement Contractor	[illegible]	[illegible]	[illegible]

We have compared the above account with the vouchers, and find it correct.

We have also verified the investment of [illegible]

January [illegible], 18[illegible]

[illegible]
[illegible] } Auditors.

ANNUAL GENERAL MEETING.

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The following is a list of excursions made during the past year. Detailed reports will be found in parts 8 and 10 of the PROCEEDINGS, vol. xv:

DATE.	PLACE.	DIRECTORS.
April 7 to 12 (Easter)	Bridport and Weymouth.	Rev. Prof. J. F. Blake, M.A., F.G.S., W. H. Hudleston, M. A., F.R.S., S. S. Buckman, F.G.S.
April 23	Reading.	J. H. Blake, F.G.S.
May 7 (Whole Day)	Hillmorton and Rugby.	Beeby Thompson, F.G.S., F.C.S.
May 14	Ayot Green and Hatfield.	J. Hopkinson, F.L.S., F.G.S., A. E. Salter B.Sc., F.G.S.
May 21	Penn and Coleshill.	W. P. D. Stebbing, F.G.S.
May 28 to June 1 (Whitsuntide)	Aldeburgh, Westleton, and Dunwich.	W. Whitaker, F.R.S. Pres. G. S., F. W. Harmer, F.G.S., E. P. Ridley, F.G.S.
June 11	Godalming.	T. Leighton, F.G.S.
June 18	Crowborough.	G. Abbott, M.R.C.S., R.S. Herries, M.A., Sec. G.S.
June 25 (Whole Day)	Sudbury.	J. W. Gregory, D.Sc., F.G.S.
July 2	Kingswood and Walton-on-the-hill.	W. Whitaker, F.R.S., Pres. G. S., W. P. D. Stebbing, F.G.S.
July 9	Upper Warlingham and Worm's Heath.	W. Whitaker, F. R. S., Pres. G.S.
July 16 (Whole Day)	Sheppey.	W. Whitaker, F.R.S., Pres. G.S., T. V. Holmes, F.G.S., W. H. Shrubsole, F.G.S.
July 23	Cycling Excursion to Purley, Coulsdon, and Merstham.	Rev. Prof. J. F. Blake, M.A., F.G.S.
July 28 to Aug. 3 (Long Excursion)	Birmingham District.	Prof. C. Lapworth, LL.D., F.R.S., W. Jerome Harrison, F.G.S., W. Wickham King, F.G.S., T. Stacey Wilson, M.D., M.R.C.P., Prof. W. W. Watts, M.A., Sec. G.S.
September 10	Gravesend.	G. E. Dibley, F.G.S.

The interest of the members in the excursions during the past year has been fully maintained.

Your thanks are due to the Directors of the excursions and also to the following ladies and gentlemen for assistance and hospitality:

The Mayor of Bridport, at Bridport; Mr. Aubrey Strahan F.G.S., for illustrations for the April Circular; Mr. Llewellyn Treacher at Reading: Mr. Young, of Rugby; Mr. W. H. Williams,

ANNUAL GENERAL MEETING.

February 3rd, 1899.

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GEOLOGISTS' ASSOCIATION.

Income and Expenditure for the Year ending Dec. 31st. 1898

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance from 1897	42	15	11	By Printing "Proceedings"	105	5	3
" Life Compositions	20	5	0	" " Monthly Circulars	19	2	0
" Admission Fees	11	10	0	" Miscellaneous Printing	16	0	11
" Annual Subscriptions (less 10s. returned) ...	170	15	0	" Illustrating "Proceedings" and Circulars ...	13	18	6
" Dividends on Nottingham Corporation Stock ...	23	16	2	" Postages	33	3	7
" Sale of Publications	8	18	3	" Addressing	7	7	0
" Sale of "Record"	4	6	0	" Library (including Honorarium to Librarian of St. Martin's Library)	18	7	9
" Sale of "Paris Basin"	0	8	4	" Attendance, Lighting, Lantern, etc., at Evening Meetings	16	17	0
				" Excursions	9	0	4
				" Insurance	2	0	0
				" Stationery	1	8	9
				" Miscellaneous Expenses	1	17	0
				" Balance at Bank of England, Dec. 31st, 1898...	33	6	7
	£282	14	8		£282	14	8

Outstanding Assets and Liabilities, Dec. 31st, 1898.

Assets.		Liabilities.	
Due from Advertisement Contractor...	£11 16 6	Due to Printers, on account of 1898...	£21 16 2

We have compared the above account with the vouchers, and find it correct.
We have also verified the investment of £820 16s. 10d. Nottingham Corporation Stock.

A. S. KENNARD, } *Auditors.*
R. HOLLAND, }

January 10th, 1899.

The additions to the Library mainly consisted of serials. Among those new to the Library may be mentioned *The Naturalist* and the "Bulletins of the Société Linnéenne de Normandie."

Some further arrears of binding have been made up. Among other works, the *Transactions* of the following societies have been bound and transferred to St. Martin's Library: Philadelphia Academy of Natural Sciences (21 vols.), Yorkshire Geological Society (6 vols.), Royal Physical Society of Edinburgh (6 vols.), Berwickshire Natural History Club (8 vols.), also *The Scottish Geographical Magazine* (10 vols.). A card catalogue is in course of preparation, and can be seen by members at St. Martin's Library.

The following is a list of the papers read at the evening meetings:

"Palæolithic Man," being the address of the retiring President, E. T. NEWTON, F.R.S.

"Pebbly and other Gravels of Southern England," by A. E. SALTER, B.Sc., F.G.S.

"Fossil Sharks and Skates, with Special Reference to those of the Eocene Period," by A. SMITH WOODWARD, F.L.S., F.G.S., F.Z.S.

"Sketch of the Geology of the Birmingham District, with Special Reference to the Long Excursion of 1898," by Professor C. LAPWORTH, LL.D., F.R.S., with contributions by Professor W. W. WATTS, M.A., Sec. G.S., and W. J. HARRISON, F.G.S.

"Contributions to the Geology of the Thame Valley," by A. M. DAVIES, A.R.C.S., B.Sc., F.G.S.

Lectures were delivered by L. L. BELINFANTE, M.Sc., on "Excursions in Russia made in connection with the International Geological Congress, 1897"; by H. W. MONCKTON, F.L.S., F.G.S., the Rev. Prof. J. F. BLAKE, M.A., F.G.S., AUBREY STRAHAN, M.A., F.G.S., and W. WHITAKER, B.A., F.R.S., P.G.S., on "The Excursion Programme for 1898"; by AUBREY STRAHAN, M.A., F.G.S., on "Observations in Lapland"; and "Notes on Skye," by HORACE WOODWARD, F.R.S. Your thanks are due to all these gentlemen.

A Conversazione of a very successful character was held in November. A full list of the exhibits will be found on p. 59 of the PROCEEDINGS. Your thanks are due to the numerous members who contributed to the success of that evening.

The following Museums and Collections were visited in 1898:

March 5th.—The Museum of Practical Geology, Jermyn Street, under the direction of the PRESIDENT, F. W. RUDLER, F.G.S., Curator of the Museum, and E. T. NEWTON, F.R.S.

March 26th.—The South Kensington Museum (Science Division), Western Galleries. Director, Prof. J. W. JUDD, C.B., LL.D., F.R.S.

June 1st.—The collection of coins and other objects of interest found on Dunwich Beach, at Mr. Lingwood's studio, Dunwich.

The following is a list of excursions made during the past year. Detailed reports will be found in parts 8 and 10 of the PROCEEDINGS, vol. xv:

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FIG. 1.—SKETCH-MAP OF BRITTANY, SHOWING THE CHIEF ANTICLINALS OF THE COUNTRY AND THE THREE PRINCIPAL SYNCLINALS.

synclinals contain the more recent beds, while the anticlinals expose the older beds.

The sketch-map (Fig. 1) will show at a glance the three principal folds enclosing rocks of Devono-Carboniferous age (the basins of Laval, Angers, and Ancenis), and the two principal anticlinals corresponding with uplifts of pre-Cambrian gneiss (Folds of Léon and Cornouaille).

A number of other less important wrinkles occur corresponding to many undulations of the Silurian and pre-Cambrian formations, but for our present purpose these may be neglected. The most important amongst them is the St. Malo anticline, as seen in the sketch-map.

We may thus acquire a general idea of the structure of Brittany in a single excursion by passing from north to south, and from one anticlinal to another, across the several synclines. It will, however, be preferable to make two parallel traverses, because of the scarcity of exposures, this scarcity forming the principal difficulty in surveying the country, where damp lowlands with a luxurious vegetation alternate with level tracts of bare moorland.

To understand the geology of Brittany, however, it will not suffice to consider only the succession of sedimentary rocks, which have been piled up during the pre-Cambrian and Palæozoic periods to a thickness of many thousand feet. Episodes of contemporaneous volcanicity took place at certain definite epochs during these different periods, and they recall the grand phenomena which have been described by Sir A. Geikie on the other side of the Channel. They will occupy our attention but for a moment, but, in spite of their historic interest, their tectonic importance is small when compared with the position occupied by the deep-seated masses of granite and diorite, and with the rôle which these play in the structure of the country.

In this outline, therefore, it will be convenient to give first of all a rapid review of the succession of the stratified rocks which enter into the structure of the area; we will next consider the contemporaneous volcanic phenomena, and finally give some description of the deep-seated intrusive masses.

THE LOCAL ROCK-FORMATIONS.

The Tertiary series, from the Eocene to the Miocene, exhibits a fair number of fossiliferous beds which are sometimes very rich, but these deposits are limited to the neighbourhood of the valleys, and it is only the Pliocene which has a wider extension. The Tertiary outliers rest directly on the Palæozoic rocks without any trace or indication that deposits of Mesozoic age ever existed between them.

The following is the succession of the Palæozoic and Archæan rocks:

CARBONIFEROUS	4. Shales and conglomerates of Teillé.
	3. Sandstone of Mouzeil with coal-seams.
	2. Shales of Chateaulin, with the *Productus*-Limestone of Quénon.
	1b. Porphyritic tuffs.
	1a. Conglomerates and porphyric tuffs.
DEVONIAN.	7. Shales of Rostellec.
	6. Shales of Traouliors.
	5. Shales of Porsguen.
	4. Greywacke of Fret.
	3. Greywacke of Faou { Limestone of Néhou. / Limestone of Erbray. }
	2. Sandstone of Gahard.
	1. Shales and Quartzites of Plougastel.
SILURIAN.	4. Nodular Shales with *Cardiola interrupta*.
	3. Ampelites of Poligné.
	2. Phtanites of Anjou.
	1. Sandstone of Bourg-des-Comptes.
ORDOVICIAN.	8. Limestone of Rosan.
	7. Sandstone of St. Germain-sur-Ille { Redon Sandstone. / St. Perreux Shales. }
	6. Slates of Riadan.
	5. Sandstone of Chatellier.
	4. Slates of Sion.
	3. Armorican Sandstone.
	2. Felspathic Sandstone of Fréhel.
	1. Conglomerate of Erquy.
CAMBRIAN.	3. Green or purple Flags.
	2. Shales and flaggy Quartzites, with dolomitic Limestones
	1. Conglomerate of Montfort and Bréhec.
BRIOVERIAN.	3. Green Flags of Néant.
	2. Shales, Limestones and Conglomerates of Gourin.
	1. Shales of St. Lo and of Lamballe with Phtanites.
ARCHÆAN.	3. Crystalline Schists of Groix.
	2. Mica-Schists and Amphibolites of Audierne.
	1. Gneiss of Quimperlé.

Archæan System.

The formations referred to the Archæan, crop out in two long east and west bands in Léon and Cornouaille. Three principal lithological divisions have been made, the types of which are taken from the southern band; these are (1) the gneiss of Quimperlé, (2) the mica-schists of Audierne, (3) the crystalline schists of Groix.

1. *Gneiss of Quimperlé.*—This stage forms a continuous band from Finistere to the Loire, and it will be seen at Auray. It consists of granitic or granitoid gneiss, coarse grained, with white or pink felspar, with much black mica in spots or in gneissic strings, and with granitoid and corroded quartz, the mica being sometimes replaced by fragmentary amphibole. The bands of gneiss alternate with interstratified layers of schist and amphibolite,

and pass into gneissic granites which penetrate them in the fashion of intrusions.

2. *Mica-Schists of Audierne.*—These mica-schists alternate with subordinate beds of fine-grained gneiss, with others of amphibolite, pyroxenite, eclogite, serpentine, chlorite-schist, and mica-schists, and include interstratified masses of intrusive crystalline rocks (fibrous and ribboned gneisses, hälleflintas, and gneissites). These subordinate rocks may have been injected into the mica-schists; they actually form with them long parallel bands, which can be followed from one end to the other of the southern plateau of Brittany, from the Isle of Sein to the Loire. In the Léon district this stage appears to form the base of the Archæan series, and in this, massive bands of a white leptynite alternate with the gneisses, mica-schists, and amphibolites.

3. *The crystalline schists of Groix* are a series of schistose rocks, including micaceous, chloritic, chloritoid, and carbonaceous schists, with sillimanite schists remarkable for the variety and abundance of heavy minerals which they contain (staurotide, garnet, magnetic iron, etc.): there are also subordinate bands of graphitic quartzite, of sericite-quartzite, of cipolin (pyroxenic marble), and of hornstone.

The boundaries of this stage, both above and below, are still very obscure; we have never been able to see them, and indeed their very existence may be called in question. The three divisions can certainly be distinguished by their lithological characters, but their succession is based only upon their constant order of superposition, which is the same in Brittany as in many other countries. No one, however, has seen the Brioverian strata in Brittany resting unconformably upon an eroded surface of the gneissic rocks; and the rocks known to occur as pebbles in the Brioverian conglomerates are not Archæan gneisses, but quartz, granite, granulite, and quartzite, that is to say, rocks identical with those of the Brioverian itself.

It must be confessed that the greater antiquity of the Archæan gneiss, though here admitted, is only a hypothesis. There are even reasons for believing that the theory which regards all the gneisses of Brittany as metamorphic products, dating from the beginning of the Brioverian period, makes a nearer approach to the truth.

Brioverian System.*

Above the Archæan gneisses and crystalline schists we find a series of beds which are clearly sedimentary, unfossiliferous shales, sandstones, and conglomerates, which were described by the early geologists under the name of the *Phyllades de St. Lô*. The lower limit of these St. Lô phyllades, which are more conveni-

* From the ancient name of St. Lo (Briovera).

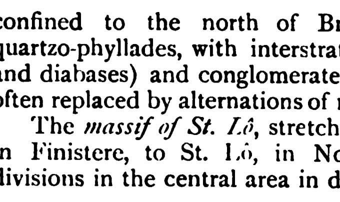
ently termed the Brioverian system, is, as we have seen, unknown. No one has yet been able to discover any unconformity in Brittany between the Brioverian and the more ancient rocks; on the contrary, there appears to be everywhere a stratigraphical and lithological passage from one to the other, so gradual and insensible that the line of division is purely subjective, and has been drawn at different horizons by different surveyors on the staff of the Geological Survey of France.

The Brioverian deposits are succeeded unconformably by the Cambrian conglomerates of Montfort, in which their débris is found as derived pebbles. We agree with Dufrènoy, who founded the system of St. Lô, in thinking that the Brioverian corresponds with the Longmyndian; but only a fortunate discovery of fossils can determine whether we should class the Brioverian as Cambrian or pre-Cambrian.

Whatever may be their relative age, the study of the divisions of the Brioverian presents great interest, because it involves the history of the first sediments and of the first volcanic eruptions in Brittany. This series appears to attain a thickness of five kilometres, and furnishes, moreover, forcible testimony to the power and unlimited extent of contact-metamorphism at a great depth.

Recent researches have shown that the seas in which the Brioverian sediments were deposited were already differentiated in Brittany. Three distinct contemporaneous facies can be distinguished in passing from north to south—facies which can be followed indefinitely toward the west and east — constituting the three massifs of Trégorrois, of St. Lô, and of the Basse-Loire.

FIG. 2.—A DEFORMED GRANITIC PEBBLE (G), WITH TWO QUARTZ VEINS (Q) IN THE SCHISTOSE CONGLOMERATE OF CESSON.



The *massif of Trégorrois* is confined to the north of Brittany; it includes shales and quartzo-phyllades, with interstratified eruptive rocks (porphyrites and diabases) and conglomerates. The whole group, however, is often replaced by alternations of micaceous and hornblende-schists.

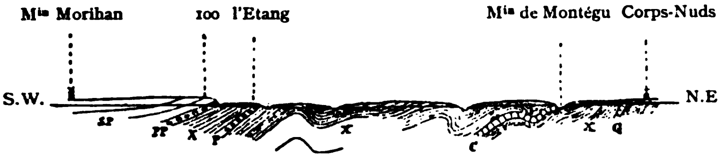
The *massif of St. Lô*, stretching from the Bay of Douarnenez, in Finistere, to St. Lô, in Normandy, exhibits the following divisions in the central area in descending order:

Brioverian System.	3. Green flags of Néant (x^c).	
	2. Shales and conglomerates of Gourin (x^b)	5. Shales. 4. Conglomerate of Gourin. 3. Shales and quartzo-phyllades. 2. Limestone of St. Thurial. 1. Phyllades.
	1. Shales of St. Lô and of Lamballe (x^a)	2. Shales with seams of black chert. 1. Shales, phyllites and greywackes.

The *massif of the Basse-Loire* presents a great development of argillaceous shales, with intercalated beds of coarse arkose, described under the name of the shales and arkoses of Bains.

These three types will be visited in succession during the course of the excursion; the central and most important massif is not well exposed in the neighbourhood of Rennes, but the section (Fig. 3), taken at a little distance from Rennes, gives a better idea of the various members of the series. The super-

FIG. 3.—SECTION FROM CORPS-NUDS TO THE MORIHAN MILL.
(Scale, $\frac{1}{80000}$)



S.P., Purple Shales; P.P., Purple Cambrian Conglomerate; X, Phyllades of St. Lô; P, Gourin Conglomerate; C, Corps-Nuds Limestone; G, White Brioverian Sandstone.

position of the conglomerates of Montfort, as indicated in this section, will be seen in the course of the excursion at Pont Réan, in the valley of the Vilaine (Fig. 4).

Cambrian.

None of the Cambrian faunas, neither of Olenellus, Paradoxides, or Olenus, have yet been found in Brittany, and if any deposition of sediment took place at these epochs, they are represented by beds which are destitute of the characteristic fossils. The most ancient fauna hitherto recognised is that of the Armorican sandstone of Ordovician age.

In the absence of palæontological evidence the limits assigned to the Cambrian are necessarily very arbitrary. For a long time the Brioverian was included in it, but at the present day only the following unfossiliferous beds are referred to the Cambrian.

These beds exhibit remarkable local developments in the different massifs with great differences of thickness and of lithological composition. The following are the principal divisions that have been recognised, in descending order:

6. Green and purple shales, and sandstones with *Lingula criei.*
5. Quartz porphyry of Pors-Even (lava flows).
4. Felstone of Arcouest, consisting of many successive outbursts.
3. Porphyrite of Kerity, with volcanic tuff.
2. Green and purple slates, nodular flagstones, dolomitic limestones and quartzites of Plouëzec and Mayenne.
1. Conglomerate of Montfort and of Bréhec.

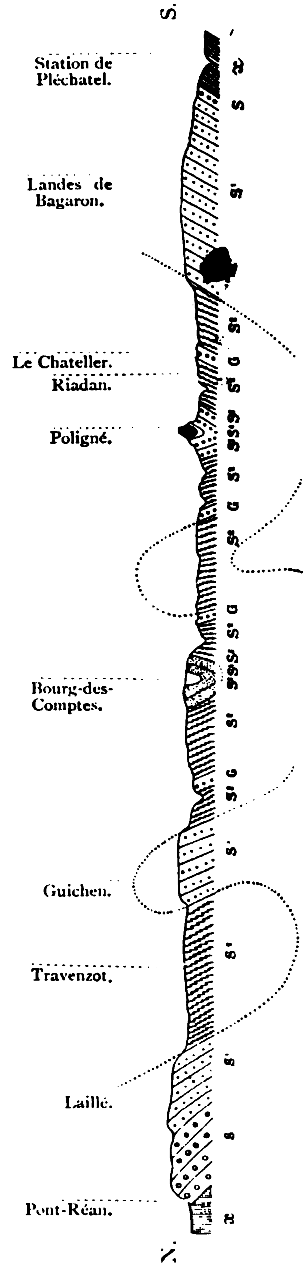


FIG. 4.—SECTION ACROSS THE SYNCLINAL OF POLIGNÉ, ALONG THE VILAINE VALLEY. (Scale, $\frac{1}{100000}$.)

S^4 Silurian. S^3 Slates of Riadan. G Sandstone of Chatellier. S^2 Slates of Sion.
S^1 Armorican Sandstone. S Cambrian. x Brioverian.

Both the volcanic rocks and the limestone bands, which occur in this series, are wanting in the Vilaine section (Fig. 4), where the clastic rocks attain their greatest development. We shall see their exposures in the Bréhec section (Fig. 5, Bay of St. Brieuc), but they have their greatest development to the east, in the Coëvrons and the Charnie, where they have been described by M. Œhlert.

Ordovician.

In the central part of Brittany the Ordovician exhibits three principal divisions, which we will examine in order.

THE LOWER ORDOVICIAN consists of the well-known Armorican sandstone, a mass of white sandstone from 1,600 to 2,600 feet thick, which plays an important part in the orography of Brittany (Fig. 6), but is poor in fossils. It includes several distinct lithological subdivisions.

1. At the base are the *Conglomerates of Erquy*, which contain fragments of hard sedimentary and eruptive rocks derived from the subjacent Cambrian and Brioverian formations.

2. Above these come

felspathic sandstones, coarse-grained rocks without fossils, which will be seen in the neighbourhood of Bréhec. Southward, in the valley of the Vilaine, they are represented by very different sandstones or grits without felspar (grès du Grand-Gouin). These should correspond with the Tremadoc Beds.

3. The *Armorican sandstone* proper (or grès du Toulinguet) consists of sandstones in more distinct beds alternating with some shaly layers. This division is more fossiliferous, yielding *Scolites*, *Bilobites*, *Lingula*, *Dinobolus*, *Asaphus* and various Lamellibranchs (*Actinodonta*, *Ctenodonta*, *Redonia*). A study of the fauna shows more analogies with that of the Arenig than with that of the Tremadoc.

MIDDLE ORDOVICIAN.

The stage of the "schistes d'Angers" presents a series of black slates, interrupted by occasional beds of sandstone, the thickness of which sometimes increases at the expense of the slates. The following subdivisions can be distinguished:

4. Bed of oolitic ironstone.

4a. The *Sion slates* with *Synhomalonotus tristani*, *Asaphus guettardi*, *Calix murchisoni*. This is the zone of geminiform Didymograpti.

5. The *Chatellier sandstone*; the stratigraphical position of this can be easily determined at Chatellier,

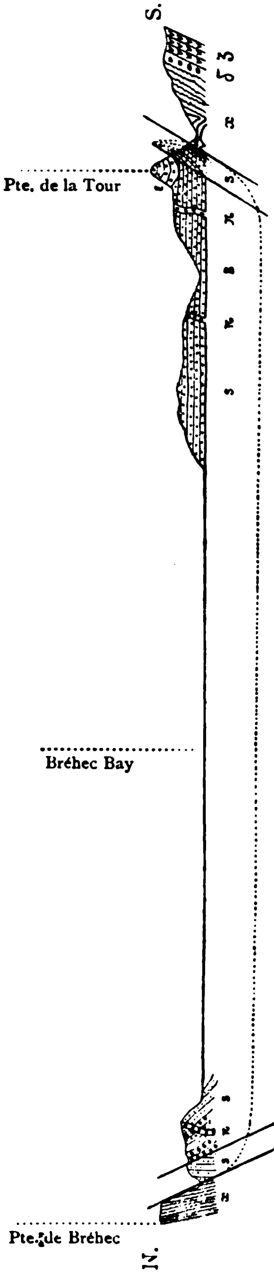
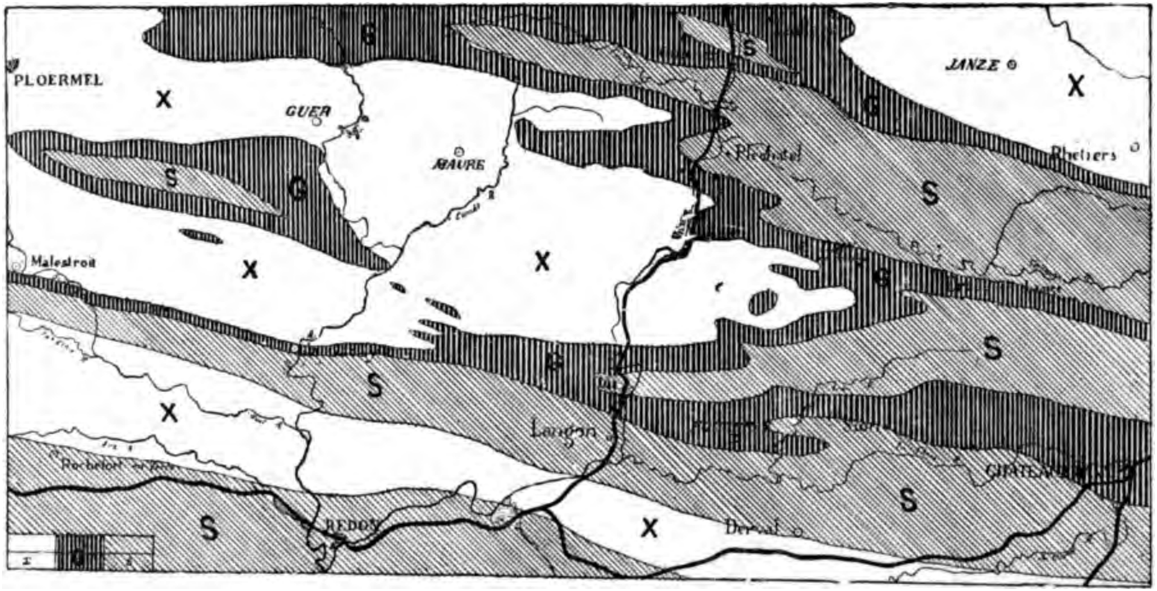


FIG. 5.—SECTION OF THE BREHEC CLIFFS. (Scale, $\frac{1}{10000}$.)

ε Flows of diabase. π Dykes of Orthophyre and of Porphyrite. s Cambrian Flags, Sandstones, and Conglomerates. *x* Brioverian Shales. δ Chlorite-schists 3 Mica-schists and Gneiss.

FIG. 6.—MAP OF THE ARMORICAN SERIES IN THE VILAINE VALLEY. (Scale $\frac{1}{500000}$.)



X. Brioverian.
G. Armorican Sandstone.
S. Ordovician and Silurian strata overlying the Armorican Sandstone.

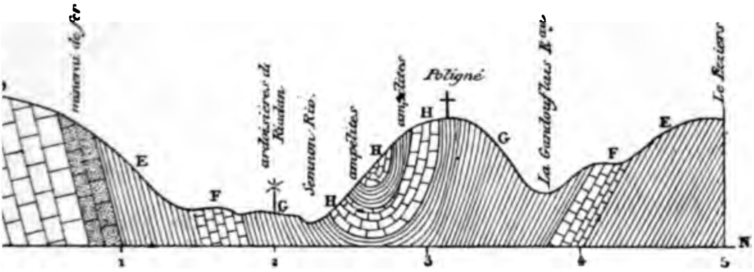
iear Bourg-des-Comptes. M. Lebesconte has found fossils in it t Thourie.

6. The *Riadan slates* with *Trinucleus pongerardi.* These lates are not easily distinguished from those below when the andstone is wanting.

Beds 4 and 4a correspond with the Llanvirn series. Beds 5 ind 6 with the Llandeilo.

UPPER ORDOVICIAN (7). *Sandstones of St. Germain-sur-Ille,* of Redon (in part), of Raguenez and Kermeur, with *Acaste incerta, Synhomalonotus arago,* and *Trinuclei*; zone of Diplograptidæ. These sandstones alternate with slaty beds of greater or less

—SECTION OF THE ORDOVICIAN BEDS AROUND POLIGNÉ, BY M. LEBESCONTE.



lites, H, Grits of Bourg-des-Comptes ; G, Slates of Riadan ; F, Sandstones of Chatellier ; E, Slates of Sion ; D, Armorican Sandstone, Iron-stone.

(Block kindly lent by the Geological Society of France.)

iickness ; they break up more easily than those below into andy flags with characteristic parallel faces. They correspond ɔ the Glenkiln Beds.

The Upper Ordovician in Finistere has been divided into wo portions by M. Kerforne, the shales of Raguenez at the base nd the Kermeur sandstone above, divisions which in the entre of Brittany are represented respectively by the red and reen slates of St. Perreux and by the sandstone of Redon. It succeeded directly at Redon and Bourg des Comptes (Fig. 4) by ie sandstones and slates of the Upper Silurian, which differ but lightly in their lithological characters. Thus it is very difficult to etermine the plane of separation between the Ordovician and ilurian systems in that part of Brittany which will be visited y the Association, but it is much more clearly marked in Finistere nd in the Maine-et-Loire, where it is found to coincide with the orizon of the limestone of Rosan. The accompanying section

(Fig. 7) shows how the beds are exposed in the neighbourhood of Poligné.

8. *Limestone of Rosan*, with *Trinucleus*, *Orthis actoniæ*, and *Triplesia spiriferoides*, fossils which lead us to regard it as the equivalent of the Caradoc. Interstratified with these calcareous rocks there are lava flows, fragmentary material, tuffs and other contemporaneous eruptive rocks. These are, moreover, limited to this horizon, of which they are characteristic in western Brittany.

Silurian.

The Silurian of Brittany is easily distinguished as a whole from the slates and sandstones of the Ordovician, by its lithological characters. Coarse, clastic deposits, such as grits and conglomerates, become rare; contemporaneous eruptive rocks are absent, we find thin beds denoting a facies of deeper water, nodular *Orthoceras* - limestones, carbonaceous slates with Pteropods (*Hyolites*) and cherts with Graptolites. The formation thus exhibits that prevailing character of carbonaceous slate with nodular *Orthoceras*-limestones which it maintains throughout the whole of the great central-European area. The number of species, moreover, which it has in common with the Silurian (E.) of Bohemia and of England is greater than in the case of the Ordovician.

The following sub-divisions have been recognised in the Silurian of the valley of the Vilaine.

1. *Sandstone of Bourg-des-Comptes* and of Redon (in part). This is unfossiliferous, and has been confused with the Ordovician sandstone, from which it is hard to separate it when the Rosan limestone is absent. It is penetrated by a larger number of quartz-veins, it is less gritty, and includes thin layers of carbonaceous shale.

2. *Phtanites of Anjou*. Cherts in thin laminæ of a few centimetres thick, but attaining a total thickness of 65 feet. The rock is remarkable for the absence of quartz-grains and of other terrigenous débris, and consists essentially of organic and chemically-formed matter. It contains about 70 per cent. of silica in various states with 10 per cent. of carbon, both equally derived from the remains of contemporaneous organisms, such as Radiolaria with opaline tests and Graptolites with a chitinous polypary. Sections of Radiolaria are sometimes seen in the thin laminæ; the Graptolites are few in number, but are very well preserved; they include *Monograptus lobiferus*, *Diplograptus*, *Climacograptus*, *Cephalograptus*, *Rastrites*; a fauna characteristic of the Llandovery.

3. *Ampelites of Poligné*.—Fine slates, without fossils, containing intercalated beds of ampelitic (carbonaceous) slate with Graptolites.

Such is the zone of Poligné containing *Monograptus crassus*, Lapw., *M. priodon*, Bronn., *M. convolutus*, var. *spiralis*, *Diplograptus palmeus*, Barr. and *Cephalograptus folium*, His., and corresponding to the summit of the Tarannon Beds.

The carbonaceous schists of Menardais and Andouillé belong by their fauna to the Wenlock age—*Monograptus priodon*, *M. galaensis*, *M. riccartonensis*, *M. vomerinus*, *M. continens*, and *Retiolites geinitzianus*.

4. *Nodular slates with Cardiola interrupta*. These are poor in fossils but include some layers of spheroidal siliceo-calcareous nodules with *Orthoceras styloideum*, Barr., *O. subannulare*, Muenst., *Bolbozoe anomala*, Barr., *Cardiola interrupta*, Sow., *Mytilus esuriens*, Barr., *Panenka humilis*, Barr., *Vlasta insons*, Barr., *Pterinea mira*, Barr., and *Dualina secunda*, Barr., and many Graptolites of Wenlock species. It is a fauna of Orthoceratites, Graptolites and thin-shelled Lamellibranchs, and is remarkably deficient in Trilobites and Brachiopoda.

Devonian.

The higher Devonian beds, which are thin and pelagic in character, occur only at a few places; the lower stages are thicker and consist of coarser-grained rocks.

1. *Shales and quartzites of Plougastel*, a thick mass of alternating beds, less fossiliferous than those above, and attaining their greatest development in the west of Brittany (=Gedinnien).

2. *Sandstone of Gahard*, a white sandstone with layers of ironstone, containing *Orthis monieri*, *Spirifer pellico*, *Homalonotus*, and many Lamellibranchs (=Taunusien).

3. *Greywacke of Néhou*. Bluish gritty shales alternating with brown greywackes and lenticles of blue limestone; these beds form a continuous band from Brest to Laval. Fossils are abundant in the limestone lenticle of Bois-roux. The Néhou fauna includes: *Spirifer hystericus*, Schlt., *Athyris undata*, Defr., *Chonetes plebeia*, Schnur. (zone of *Spirifer hercyniæ*). The best localities described by M. Œhlert occur near Laval. The limestone lenticles which yield the fauna of Erbray (zone of *Sp. primævus*) are older than that of Bois-roux, and are better developed in the basin of Angers than in that of Laval or of Finistere.

4. *Greywacke of Fret*, with *Phacops potieri*, Bayle, *Spirifer auriculatus*, Sandb., and *Sp. paradoxus*, Schlt., is seen near St. Aubin d'Aubigné (zone of *Spirifer paradoxus*).

5. *Slates of Porsguen* with *Anarcestes subnautilinus*, Schloth. *Bifida lepida*, Goldf. (=Eifelien).

6. *Slates of Traouliors* with *Rhynchonella pugnus*, Mart., *Receptaculites neptuni*, Defr. (=Frasnien).

7. *Slates of Rostellec* with pyrito-siliceous nodules, yield

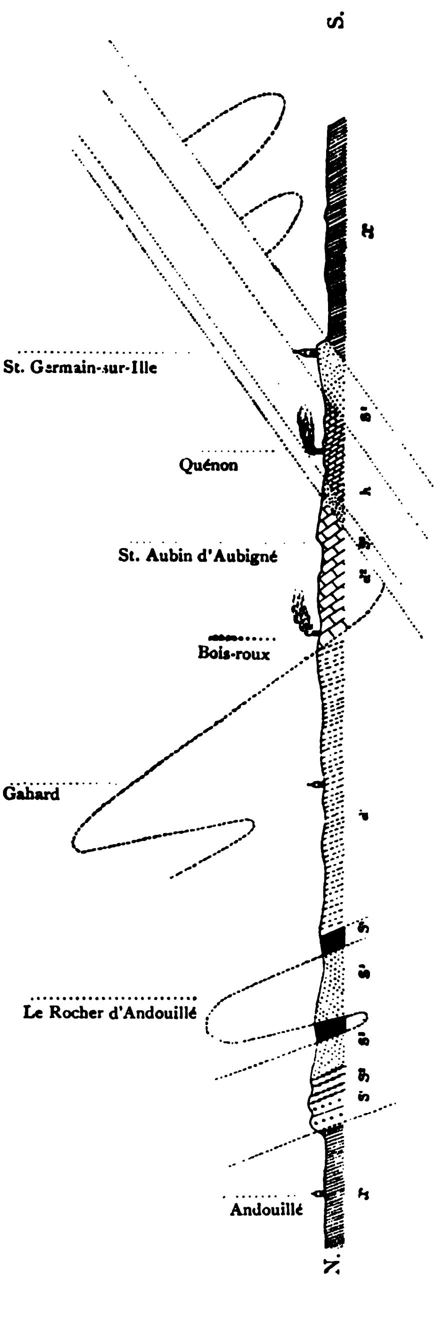


FIG. 8.—SECTION ACROSS THE SYNCLINAL OF ST. AUBIN D'AUBIGNÉ. (Scale, $\frac{1}{40000}$.)

h. Carboniferous Strata. d^2. Greywacke of Faou. d^1 Gahard Sandstone. S^4. Silurian. S^3. Sandstone of St. Germain-sur-Ille. S^2. Slates of Angers. S^1. Armorican Sandstone. *x*. Brioverian.

Parodiceras verneuili, Muenst., *Tornoceras simplex*, v. Buch. (=Famennien).

The portion of Brittany which will be traversed by the Association is unfavourable for the detailed study of the Devonian. To those who may wish to make a more prolonged examination of this formation we should recommend the neighbourhood of Laval or of Brest.

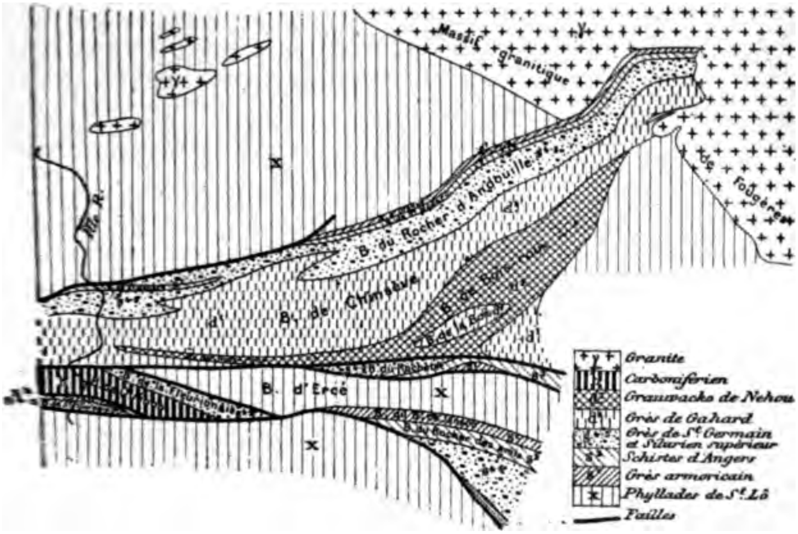
Carboniferous.

The oldest Carboniferous sediments in Brittany are deposits of eruptive material spread out on the old sea floor. The period is characterised in this region (studied by MM. E. and L. Bureau) by alternations of terrestrial and marine conditions, as well as by grand and powerful

volcanic phenomena; it is a period of great eruptions and of great earth-movements.

1. *Porphyroids.* In the west of Brittany we find shales and conglomerates, with porphyric material and porphyritic tuffs. In the central area there are shaly rocks crowded with crystals of felspar, and of bipyramidal quartz (porphyroides and blavierites), which attain a thickness of 3,000 feet (Eréac). Some beds exhibit a structure like that of microgranulite and of quartz porphyry; but others contain pebbles, and are clearly of clastic origin (as at La Barillère).

FIG. 9.—SKETCH-MAP OF THE ST. AUBIN D'AUBIGNE MASSIF.
(Scale $\frac{1}{200000}$)



2. *Slates of Châteaulin.* These are bluish grey, fine-grained shaly beds with *Productus* (at Lande-Marie in the Rennes sheet), alternating with layers of greenish grey felspathic sandstone with vegetable impressions (in the Chateaulin sheet). They include a thick lenticle of limestone worked for marble in the quarries of Quenon (Fig. 8); the beds are vertical and fossiliferous, affording *Phillipsia*, *Productus*, etc. The section (Fig. 8) shows how the beds are broken in the synclinal troughs of Central Brittany. The accompanying sketch-map (Fig. 9) of the region shows how the faults can be followed and traced in the field.

The slates of Chateaulin are represented in the basin of Ancenis by greywacke with plant remains, corresponding to that of Thann (Culm).

3. *Mouzeil sandstone* with coal seams, comprising alternating beds of shale, sandstone, conglomerate and porphyritic tuff (pierre carrée). The conglomerates contain pebbles of quartz, gneiss, diabase, Silurian quartzite, Carboniferous chert, and greywacke. The flora is that of the greywacke of the Culm, *Bornia transitionis*, F. Roem; *Sigillaria minima*, A. Brg.; *Knorria imbricata*, Stern.; *Lepidodendron veltheimianum*, Ung.; *Archæopteris virleti*, Stur.; *Neuropteris antecedens*, Stur.

4. *Shales of Teillé*, crowded with plant remains, and alternating with beds of conglomerate, containing pebbles of quartz and Carboniferous greywacke. Fossils: *Cordaites borassifolius*, Gein.; *Alethopteris serlii*, Goepp.; *Prepecopteris plumosa*, Grand Eury; *Sphenopteris furcata*, A. Brg.; *Asterophyllites longifolia*, A. Brg. A still higher horizon with *Dictyopteris subbrongniarti*, Grand Eury, has also been recognised by M. Bureau at Ecoulé. The conglomerates of this age at Quimper contain pebbles of granite and of various gneisses.

II.—ERUPTIVE ROCKS.

As the route was not chosen with the special view of studying the contemporaneous volcanic rocks, the Association will not be able to see much of them during the excursion. We shall therefore confine ourselves to enumerating the principal eruptive episodes, without describing them in detail.

Brioverian: Diabases, epidiorites, porphyrites, and variolites of the Trégorrois.

Cambrian: 1. Pyroxene-porphyrite of Kerity; flows of porphyritic glass, tuffs, and agglomerates.

2. Orthophyres of Arcouest, comprising many successive outbursts, the veins of which cut and displace one another.

3. Quartz-porphyry of Pors-Even; microgranulites; micropegmatites; sphærulitic petrosiliceous and rhyolitic porphyries

Upper Ordovician: 1. Quartz-porphyries of the Basse-Loire. 2. Diabases and porphyrites with tuffs and ashes at Rosan.

Lower Carboniferous: 1. Quartz-porphyries, porphyroids, and porphyric tuffs. 2. Diabases, porphyrites, and porphyritic tuffs.

Upper Carboniferous: Dykes of diabase, so numerous that before denudation their lava-flows must have covered the whole country.

III.—INTRUSIVE ROCKS.

In the number and variety of its granitic masses, in their diversity of structure and composition, in the great faults which have brought deep-seated portions to the surface, and lastly in the

depth to which the country has been eroded since the Carboniferous period, Brittany offers remarkable opportunities for the study of intrusive igneous rocks. The granites intruded at different epochs, ranging from the Archæan to the Carboniferous, do not always show the same relations to the surrounding strata, and a study of these relations throws light on the mechanism of their outbreak.

But while the relations of the granites to the Palæozoic sediments are similar to those of other countries, such as England and Norway, where Palæozoic rocks repose directly on the crystalline schists, we find in Brittany other facts and special conditions between the Cambrian and the Archæan, in a clastic formation more than four kilometres in thickness. In these deep-seated Brioverian sediments the Carboniferous granitic intrusions have here been subjected to very considerable pressure, due to the weight of the overlying sediments, and the modifications produced have consequently been more intense; it is in these beds that the phenomena of metamorphism and injection attain their greatest development.

Putting aside the general problem so ably discussed from such very different points of view by Michel Lévy and Brögger, we shall limit ourselves, in what follows, to the description of mere facts, which may be observed during the progress of the excursion.

(*a*) *The granite mass of St. Marcan and its granulitic aureole* (Fig. 10).

This mass is circular in form and occupies an area of about 50 sq. kil. It has forced its way into the Brioverian slates and greywackes which have been transformed near the contact into spotted and knotted schists, leptynolites, chiastolite slates, and micaceous greywackes. It is formed of a medium-grained, homogenous, massive rock of a bluish-grey colour, rich in white orthoclase, greenish oligoclase, microcline, and a black mica which is present in excess of white mica. The amount of white mica increases as the margin is approached, and at the margin the rock can no longer be distinguished from a muscovite granulite.* Smaller masses, Mont Dol, Tombelaine, and Mont St. Michel, consisting of granulitic rocks, aplites, and pegmatites occur as satellites to the main mass in isolated knobs.

This fact of differentiation is better seen round the mass near Dingé, and, better still, round the granitic masses of Gueméné; it is general, but of unequal extent.

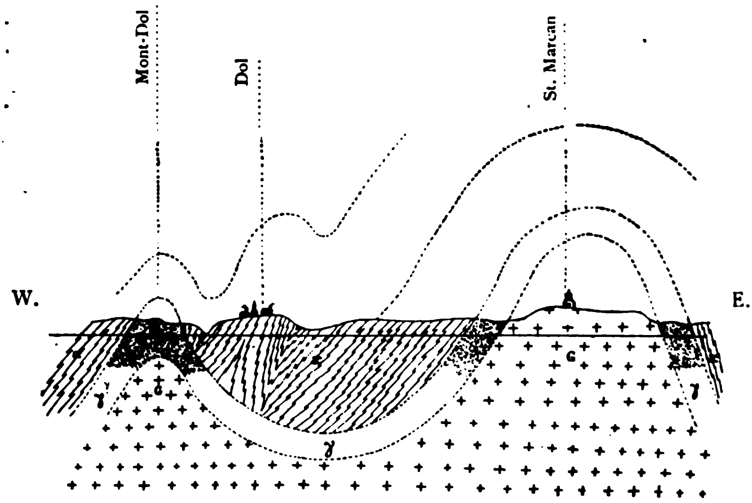
(*b*) *Granitic masses of the Morbihan.*—Many granitic masses occur in the Morbihan; they are so numerous and so like each other that no doubt can exist as to their genetic relations. Do these different masses represent, as in certain countries, successive

* It must be remembered that French authors use the term "granulite" for muscovite granite, and even for a granite with two micas.—ED.

intrusions, emitted from the same reservoir during a process of slow differentiation, or do they, rather, correspond to the different parts of one liquid mass, consolidated at different depths and at different times?

They differ more in the forms of their contours and in their modes of distribution than in their lithological characters. The different masses have many lithological features in common, and share a general tendency to arrange themselves, like beads on a string, in a series of elliptical areas, extending from north-west to south-east. These strings of granitic beads, so to speak, can be

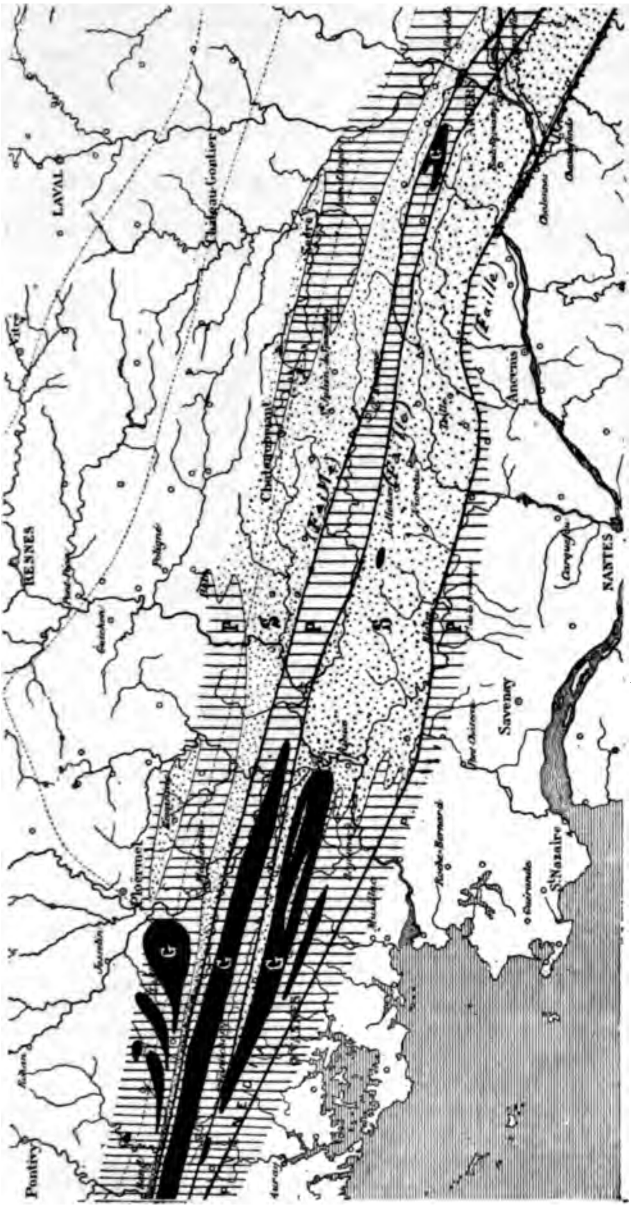
FIG. 10.—SECTION THROUGH THE GRANITIC MASS OF MONT-DOL. (Scale, $\frac{1}{80000}$)



x Brioverian. γ Aplites and Granulites. G Granite.

followed for a distance of 300 kil. along the southern margin of Brittany. The direction of the moniliform lines corresponds to that of the folded Palæozoic rocks and to that of the principal tectonic features, such as faults and the crests of folds. But while in the N.W. of the district the granitic masses are exposed in the areas of pre-Cambrian gneisses and mica-schists, in the S.E. they occur also in the Silurian area. It is easier to study them in the Palæozoic districts rather than in the pre-Cambrian area; we shall therefore select the Palæozoic S.E. of Brittany for

FIG. 11.—SKETCH-MAP SHOWING THE EASTERN TERMINATION OF THE THREE GRANITIC MASSES OF SOUTHERN BRITTANY.
(Scale, $\frac{1}{1000000}$.)



P. Pre-Cambrian (Archæan and Brioverian). S. Silurian. G. Granite and Granulite. (The chief faults are traced on the map.)

detailed description, and generalise the results so far as the western pre-Cambrian part of the country is concerned.

The field thus limited is represented on the map (Fig. 11), which shows the termination towards the E. of the following three parallel granitic zones :

1. Mass of St. Jean Brevelay.
2. Mass of Lanvaux.
3. Mass of Grandchamp.

The mass of St. Jean Brevelay is the most northerly. It extends, on our map, almost from Ploermel to Pontivy, with an area of about 200 sq. kil.

The mass of Lanvaux, situated to the S. of the one above referred to, and of greater importance, forms a vast ellipse more than 90 kil. in length. Moreover, it does not stop where last seen at the surface, for the granite which appears to the west of Angers, 80 kil. further to the east, may be regarded as an apophysis of the same deep-seated mass. The analogies in composition and structure of the granites of these two masses, the similarity of their action on the surrounding rocks, and lastly their occurrence in the centre of the same anticlinal, establishes this fact of their relationship.

The mass of Lanvaux must therefore be regarded as the longest in the district, for it extends, either at the surface or beneath it, fiom Lanvaux to Angers, a distance of 200 kil., and therefore from one end to the other of our map (Fig. 11).

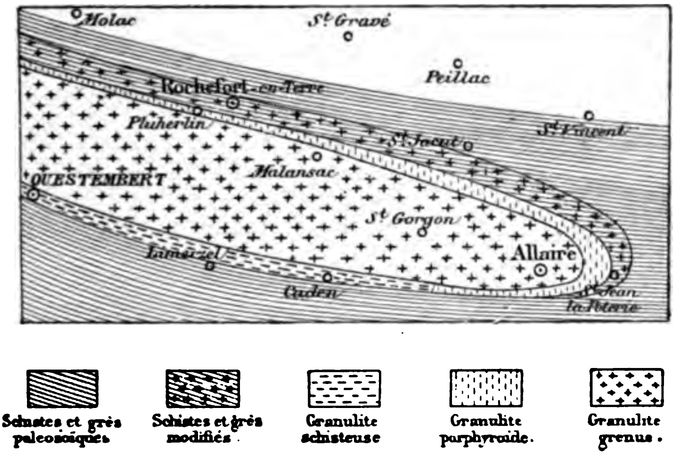
The mass of Grandchamp, situated to the south of the foregoing, extends from Pluvigner to Allaire, with an area of 300 sq. kil. It is shorter than that of Lanvaux, but, like it, reappears after an underground course of 40 kil. in the smaller mass of Nozay, which is lithologically identical with that of Grandchamp, and situated in the centre of the same Silurian synclinal. There are therefore the same reasons for referring the granite island of Nozay to that of Grandchamp as there are for correlating the granite of Angers with that of Lanvaux. The probability of their continuity underground is increased by the curious metamorphism of the Silurian sediments into crystalline schists in the intervening portion of the synclinal as indicated on the State Survey map of St. Nazaire.

The continuity underground of the elliptical masses above referred to is proved both by the similarity in their lithological characters and by their mode of occurrence. It is more difficult, and at the same time more interesting, to ascertain the relations of the three zones to each other. Some light may be thrown on the matter by comparing them with reference to the mode of occurrence of the granite, the age and nature of the metamorphism of the beds traversed, and the structure and composition of the intrusive rocks. But before proceeding to institute this com-

parison it will be necessary to study the three masses in greater detail.

1. *Mass of St. Jean Brevelay.* This mass is formed of a coarse-grained granulite with two micas. Aplitic, fibro-schistose and gneissose varieties may sometimes be observed on its margins. It is situated in an anticlinal band in Brioverian slates, which must belong to the upper part of the formation, because the purple Cambrian slates are regularly exposed on both sides.

FIG. 12.—MAP OF THE EASTERN EXTREMITY OF THE GRANDCHAMP MASSIF. (Scale $\frac{1}{320000}$)



A description of this mass has already appeared to which reference may be made (*Ann. Soc. Geol. du Nord*, t. xv., 1887, p. 16).

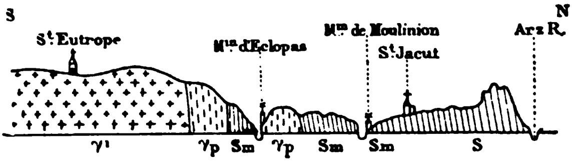
2. *Mass of Grandchamp.* This mass is allied to the former in composition and most of its other characters, but it traverses all the formations of the district from the pre-Cambrian gneiss to the anthracitic slates of the Upper Silurian. The beds are intensely altered with the development of the ordinary contact-silicates, such as black mica, andalusite, fuchsite, garnet and pyroxene. Felspar has not been produced in this outer aureole.

In the centre of the mass the granite is a coarse-grained, massive rock, rich in white mica and containing quartz grains which are generally terminated (granulite, French). Near its margins this rock becomes porphyroid and presents some important endomorphic modifications. On its southern border it becomes foliated, the mica and other constituents being orientated parallel to the foliation. On the northern side the change is somewhat different (Fig. 13); there the black mica becomes more abundant,

the constituents increase in size and the microcline occurs in large Carlsbad twins, four or five cms. across, giving to the rock a porphyritic character. The constituents are not distributed irregularly, for even small exposures show that the porphyritic crystals of microcline are arranged along undulating lines or zones. Aplite sometimes forms local margins (Tertre Windmill), but more frequently occurs as narrow veins.

From the differentiation of the magma and from the orientation of the elements of first consolidation along pseudo-fluidal lines, near the margin, we must conclude that the consolidation was progressive; and that, commencing near the margin in a still moving mass, it proceeded towards the interior across a magma at rest. The foliated granulites on the southern border possess a secondary schistosity, due to orogenesis, superimposed upon a

FIG. 13.—SECTION FROM ST. EUTROPE TO ST. JACUT, (Scale $\frac{1}{80000}$)



γ' Granulite   Sm Metamorphosed Silurian
γp Porphyroid Granulite   S Silurian Strata

primary phenomenon of fluidity due to the conditions under which the magma consolidated.

In the mass of Grandchamp the modifications of the granite at the contact are not due to interchange of material between the eruptive magma and the surrounding rock; but only to the conditions of consolidation which determined the orientation of the constituents of the granite, their mode of grouping, and the order of crystallisation. The enclosing rocks acted differently as regards the conduction of heat and the transmission of pressure, but they exerted no chemical influence on the eruptive magma. This conclusion, however, is only applicable to this mass and to the one previously described. It does not apply to the mass of Lanvaux.

The neighbouring small circular islets of granulite do not show modifications comparable to those above described. They may be regarded as the apophyses of more important masses existing below.

3. *The granite mass of Lanvaux* forms an elongated area, parallel to the former, but differing in composition and structure. It is usually foliated, and presents many varieties. Massive

granite, rich in biotite, is worked for paving-stones in the eastern portion of the area, near Bains, but the rest of the mass is gneissose, and the dominant black mica is usually present as débris; it is made up of alternating, more or less micaceous bands which possess granular or euritic, gneissose and glandular structures.

The granite of Lanvaux, unlike that of Grandchamp, does not appear in contact with beds so high in the series as Upper Silurian; it is limited to the area of the Brioverian rocks, which form a long, elliptical anticline separating the parallel synclinal troughs of Redon and Malestroit.

The greyish slates alternating with beds of darker slate, greenish grey greywackes, and beds of a white foliated arkose, are exposed from one end to the other of the "Landes de Lanvaux," in the valleys of the Claye and of the Arz. The beds of arkose, near the granite, are remarkable for the development of thick sericitic membranes, which give them a gneissose aspect and surround large grains of quartz (1-2 mms.), sometimes doubly terminated, fragments of orthoclase and oligoclase, and also fragments of black mica. As the granite is approached the slates become nodular, and small plates of black mica and muscovite are developed; moreover, the felspars of the granite pass out into the contact-rocks and transform them into felspathic schists containing a little mica. The quartz in these schists is often arranged in continuous ribbons.

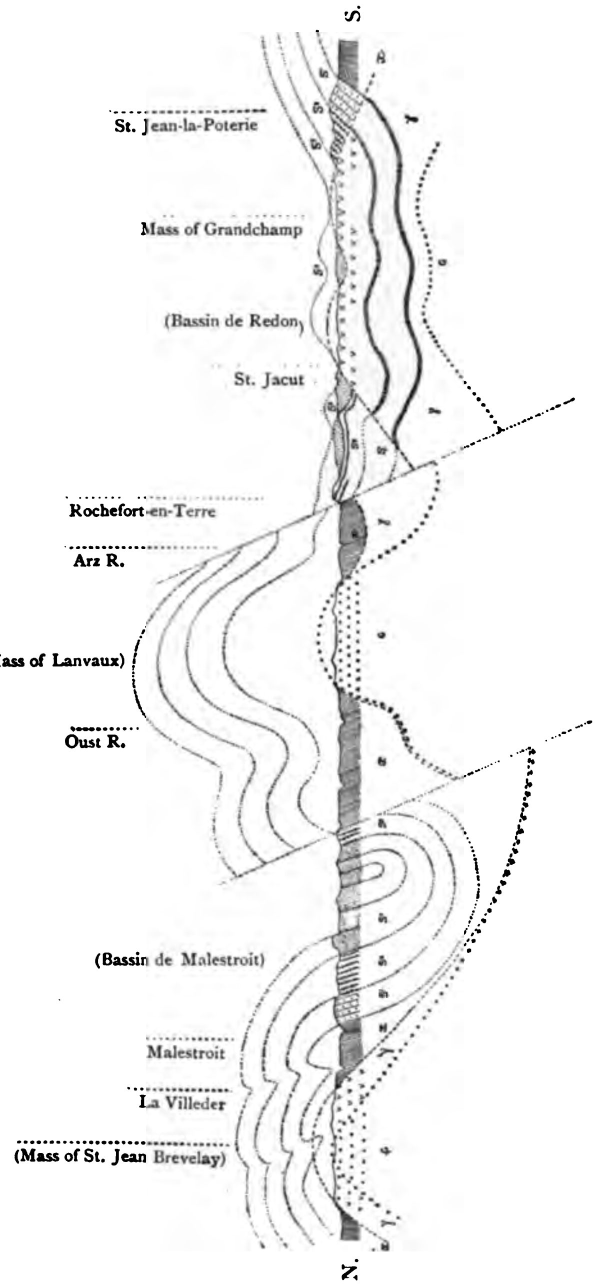
The parallel structure of the granite-mass is in part due to interstratified bands of a greenish grey, somewhat micaceous schist. Repeated alternations of more or less granular, gneissose and schistose bands point to the conclusion that there has been an injection of granitic sills between beds of schist, and do not support the view that the phyllitic and schistose bands have been formed by the dynamic metamorphism of the massive granite.

Comparison of the Three Granite Masses of the Morbihan.—If, on consulting the map (Fig. 11), a comparison be made of the three masses above described, it will be seen that the Lanvaux-mass is enclosed in the deep Brioverian beds, far away from the lines delineating the Silurian series.

The Grandchamp mass traverses Silurian rocks, while that of St. Jean Brevelay is in the neighbourhood of another band of the same age; the map, therefore, shows that the Lanvaux-mass is enclosed in beds older than those surrounding the two others.

If, moreover, we make a section (Fig. 14) across the map it will be seen that the Lanvaux-mass has not reached the general level, but that the block has been brought up by two faults, which have been traced upon the ground. If we recall the ideas already acquired on the distribution of the sedimentary rocks of the district, we are compelled to admit that before its abrasion by atmospheric denudation the rocks forming this anticlinal block

FIG. 14.—SECTION ACROSS THE THREE GRANITIC MASSES OF MORBIHAN. (Scale, $\frac{1}{100000}$.)



γ Granulite G Granites S^3 St. Germain Sandstone S^2 Angers Slates S^1 Armorican Sandstone
x Brioverian Shales

were covered by the whole thickness of the Silurian rocks now only to be seen in the neighbouring synclinals.

These facts show, beyond all question, that the granite of the masses of Grandchamp and of St. Jean Brevelay were consolidated under almost the same conditions of depth, and those of Lanvaux under different conditions and at greater depths, so it is to these differences of depths, shown in the sections, that the differences of composition and of structure between the granite masses, described above, precisely correspond. There is, therefore, a reason, *founded upon observation alone*, for believing that the differences of composition and of metamorphic action in these granites are to be attributed to the depths at which the consolidation of the various masses took place.

It may be objected that these differences may be due to other causes. Thus it is possible to suppose that the various masses are not contemporaneous, or that they belong to two successive intrusions of a magna undergoing evolution at a great depth. But on comparing the two hypotheses it will be seen that ours has the decided advantage of *resting upon material facts;* although it may not eliminate other objections. No observation actually supports the idea that the three masses described could have been formed by successive eruptions; we find neither débris nor constituents of a first consolidation, mingled with the minerals of more recent formation, nor rolled pebbles of these granites in the various members of the sedimentary formations. Other masses in Brittany have furnished examples of these facts; their absence in the district under consideration is but further proof of the synchronism of these three masses.

The characters of the granite and the extent of its metamorphic phenomena vary with the thickness of the covering cap and consequently with the pressure under which the mass consolidated; they are also in relation with the nature and abundance of the mineralising agents which accompanied the magma. The stratigraphy of the Morbihan masses furnishes an example of this by giving an explanation of the difference of the intensity and extent of the *felspathisation* in neighbouring masses, sometimes separated in the field by scarcely a mile.

Thus it is proved that in the masses which consolidated at lesser depths, such as that of Grandchamp, the separation between the Silurian and the granite is sharply defined, the sediments are not felspathised, but transformed into crystalline rocks with mica and andalusite without felspar, as is the case in Norway and in the Vosges.

In the Lanvaux-mass, on the contrary, at the contact with the granite, a persistent zone in which schists and greywackes become charged with felspar, possibly by absorption or by injection, may be observed. All the stages of this felspathisation may be followed, and almost imperceptible passages between the felspathic

schists and the granite itself may be observed; until, in the presence of certain beds, it becomes a matter for discussion whether they are granites, mechanically crushed and deformed, or felspathic schists. Veritable gneisses are thus produced, in the midst of which we find, here and there, more massive granites or fragments of schists representing extreme stages of alteration. The extent of the felspathisation and the thickness of the gneissification are therefore functions of the depth of the contact observed, and permit, so to speak, of its measurement.

It becomes reasonable, therefore, to suppose that at greater depths the contacts between impregnated sediments and granite would present less and less difference; and we are thus led to believe with M. Michel Lévy that there exists a deep zone where there is complete continuity between the normal granite and the gneissic border formed under the influence of the granite at the expense of the earlier sedimentary rocks.

But whatever may be thought of this conclusion, the stratigraphical examination of the granite-masses of the Morbihan furnishes material facts which all theories must take into consideration. Stratigraphical observation negatives the view that the granite has been an intrusive plastic mass, elevating, displacing and dislocating the superincumbent sedimentary rocks at the time of its eruption. The great tectonic lines of Brittany and the general plan of structure have not been disturbed by the eruption of the granite; the long bands of colour on the geological map, the folds and faults which affect the normal sedimentary masses of the east of Brittany, continue uninterruptedly in the west, into the granitic portions of the country, without disclosing any connection between the presence of the granite and special dislocations or more complex structures which do not exist in this district. The stratigraphical order of the sedimentary blocks within the granitic areas prevents their being considered as scattered fragments floating on the surface of a granitic bath; for the sequence is normal and the included masses lie along the same lines of strike as those of the surrounding strata from which they have been derived. The sections traced across the folded and faulted sedimentary series of Brittany may be drawn continuously, in the portions replaced by the granite masses, in the same way that they may be traced in the field over those portions removed by atmospheric denudation.

The construction of geological profiles across the country does not enable us to distinguish the forms in space of the various granitic masses, but it clearly brings out the fact that the existing surface gives us sections in plan, of masses which consolidated at different depths. These sections show that the phenomena of contact-metamorphism, of injection, of assimilation and, consequently, the composition and structure of the granites them-

selves, are variable in one and the same district and round the same centre; and, further, that these variations are a function of the distance of the section in question from the upper limit reached by the magma during its ascension.

Granites of the Côtes du Nord.—In the Côtes du Nord there is evidence of the formation of granite at several successive periods. The first, of Lower Brioverian age, is represented by pebbles in the Brioverian conglomerates; the second is found as intrusive masses in the Brioverian rocks and also as pebbles in Cambrian strata; the third shows masses which cut the Silurian series and are of Carboniferous age. These different occurrences may best be studied in inverse order.

The Mass of Quintin.—This vast elliptical mass, 50 kil. in length, is composed, on its southern margin, of massive granite with biotite and on its northern margin, of foliated granite with two micas, passing into granulitic gneiss. These differences of structure are, as in the Morbihan, in direct relation to the depth of the enclosing rocks, massive granite being found in contact with the Carboniferous series and the gneissose granite with the Brioverian. Here, however, we may suppose, and there are even arguments for believing, that the differences should be attributed to the action of two successive eruptions.

This mass of granite is instructive in other ways; it not only furnishes information as to the difference both of kind and degree of metamorphism on its different faces, but also as to the unequal resistance to assimilation of the various sediments presented to it. An example of this is to be found in the neighbourhood of Plédran at the contact of the gneissose granites (gneiss granulitiques) and the Brioverian shales. These rocks, east of Plédran, present the usual characters of the St. Lô formation—argillaceous shales with intercalated beds of greywacke and a few beds of hornblendic rocks and graphitic phtanites.

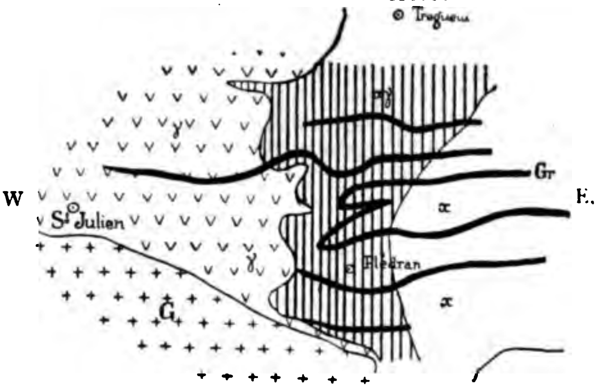
On approaching the granite mass of Quintin, from the east towards the west, the gradual alteration of the sedimentary rocks may be observed; the metamorphism of the argillaceous rocks is seen to take place more readily than that of the graphitic phtanites.

The shales pass successively into spotted schists; into micaceous schists, rich in biotite, etc., with a few macliferous and sillimanitic patches; then into felspathic schists, and finally into granulitic gneisses; the passage is very gradual between the different rocks. The gneisses contain all the constituents of the granulites, associated with the remains of the schists in the condition of continuous tissues enriched with streaks of black mica and with patches of sillimanite. The tissues give to the granulitic rock an interlaced structure, in which the wavy micaceous films separate the lenticular amygdules of massive granulite with black mica.

The beds of graphitic phtanite are far less affected by metamorphic action than are the beds in which they occur; and they may be followed in the field, as shown upon the accompanying map (Fig. 15), which illustrates the fact that definite beds of phtanite occur successively between schists, mica-schists, and granulitic gneisses as they approach the granite; the phtanite may be traced into a massive quartzite as the schists pass into gneiss.

Some geologists would prefer to consider these granulitic gneisses as crushed granite rather than as schists injected with granite, but the question appears to be of minor importance in view of the proved persistence of the bed of phtanite, neither

FIG. 15.—MAP SHOWING THE CONTACT OF GRANITE NEAR PLEDRAN. (Scale, $\frac{1}{180000}$.)



G Granite. γ Granulitic Gneiss of Brioverian Age. *xγ* Micaceous Brioverian Schists. Gr Graphitic Phtanite of the Brioverian. *x* Brioverian Shales and Greywackes.

disturbed nor dislocated, into the granitised mass. The granitic magma has taken the place of the schist, but not that of the quartzite.

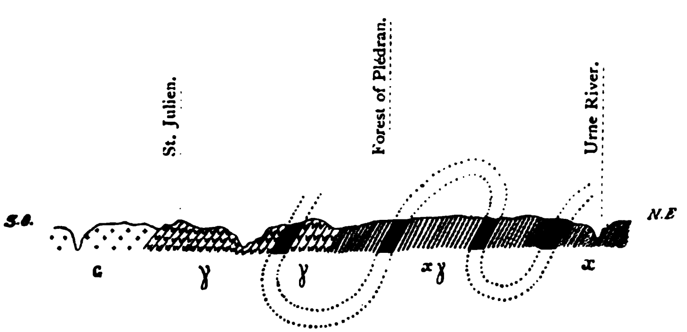
The graphitic quartzite is the actual bed from which M. Cayeux described the Radiolaria (*Cenosphæra*) obtained near Lamballe, 18 kil. distant. The age of the quartzite is as clearly established as its sedimentary origin, since it forms a well determined horizon in the Brioverian series, and is found as pebbles at the base of the Cambrian. Its great development in the Plédran district is accidental, and due to a folding, which brings the same bed to the surface several times, as shown in the section. (Fig. 16.)

2. *The granitic mass of St. Brieuc.*—The granite of St. Brieuc differs from those above described in structure, mode of occur-

rence, and age. It is more basic, containing amphibole, and occasionally passes into diorite. It is older than the others, for it occurs as pebbles at the base of the Cambrian, whilst those described above cut Silurian strata, and are of Carboniferous age.

This granite is dioritic, sometimes massive and sometimes gneissose, unequally rich in amphibole, with titaniferous iron, apatite, zoned felspars passing from andesine to basic labradorite,

FIG. 16.—SECTION SHOWING THE FOLDING OF THE GRAPHITIC BEDS AROUND PLEDRAN, AND THEIR METAMORPHISM. (Scale, $\frac{1}{150000}$).



G Granite. γ Granulitic gneiss.
xγ Micaceous schists. x Brioverian shale.
Graphitic phtanites (in black).

orthoclase rare, pyroxene rare, and quartz. It passes in its massive varieties from the hornblende-granite of St. Brieuc into the diorite of St. Quay. In the thin veins of the periphery of the mass it shows pegmatitic varieties, with crystals of amphibole 5 cm. in length, besides other varieties passing into microgranites.

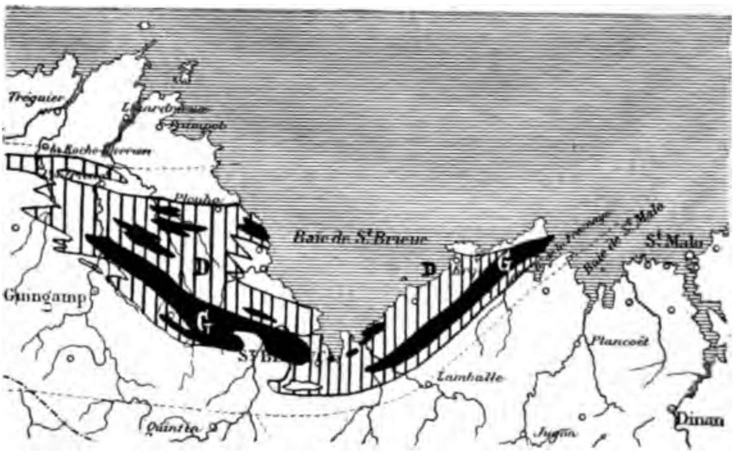
The St. Brieuc granite is only seen in contact with Brioverian rocks ; it presents endomorphic and exomorphic modifications as extensive of their kind as those of the Morbihan mass. But the modifications are no longer of the same type. The Brioverian strata here are not composed of slates and greywackes as in the Morbihan (facies of the phyllades of St. Lô), but of alternating beds of clay slates, graphitic phtanites, and basic flows (more or less abundant) of porphyrites and diabases (facies of Trégorrois) ; it has become a complex formation composed principally of green schists with actinolite, epidote and chlorite, alternating with compact green hornstones (*schistes pyroxeniques*) and foliated gabbros resulting from the transformation of massive basic rocks, together with micaceous schists, staurolite schists, leptynites, micaceous greywackes, and felspathic conglomerates.

Its appearance under this very basic facies is limited to a bow-shaped band which corresponds, in the district we are considering, to the Bay of St. Brieuc, as shown in the map (Fig. 17).

The map also shows the distribution of the pre-Cambrian hornblendic granite, and one sees that it is confined to the area occupied by the preceding basic series, which it follows closely.

It is believed that, in this coincidence, a relation of cause and effect may be observed, and that the composition—unique in Brittany—of this mass of dioritic granite, is due to the influence

FIG. 17.—SKETCH-MAP SHOWING THE DISTRIBUTION OF THE PRE-CAMBRIAN HORNBLENDIC GRANITE AND ITS TOPOGRAPHICAL RELATIONS WITH THE BASIC FACIES OF THE BRIOVERIAN STRATA. (Scale, $\frac{1}{1200000}$.)



D Basic Facies of the Brioverian Series. G Hornblendic Granite.

of the Brioverian eruptive basic rocks, also unique, into the midst of which the granite is intruded. We drew attention in 1889, in the Puy-de-Dome*, to the analogy which exists between these facts and those there pointed out by M. Michel Lévy; impressed by the constant association in that district of calcareous hornstones and diabase-diorites, and by the occurrence of an aureole of hornblendic granite between the latter and the normal granite, he concluded that the various rocks resulted from the endomorphism of the granite, its composition having been considerably changed by the assimilation of calcareous beds. In Brittany, in the neighbourhood of Pontrieux and of Andel, on ascending the Trieux river, or in descending the valley of the Gouessan, one

* *Bull. Soc. Geol. France*, t. xviii, p. 917, 1896.

may follow the passage of microlitic rocks, porphyrites and diabases, into hornblendic schists and epidiorites.

In the hornblende-schists of both valleys, on approaching the granite, grains of felspar are developed, which gradually transform the rocks into a hornblendic gneiss, a gneissose diorite, and finally into a massive dioritic granite with amphibole and biotite.

These massive crystalline rocks are well developed in the Bay of St. Brieuc; they present exceptionally ultra-basic types, such as norites, hornblendites, and even peridotites with hornblende, analogous with those recognised by M. Lacroix at Pallet in the Loire-Inférieure.

Numerous sections prove that the schistose hornblendic hornstones, and other associated Brioverian rocks, are disrupted by the diorite and intimately mixed with it in the form of a breccia with its angular elements in alignment; occasionally the injection occurs in slender, transverse veins, or more often following the lines of foliation, which at the same time are penetrated in all directions and in all proportions by the dioritic magma (see the survey map *Bande de Coëtmieux*).

IV.—GENERAL STRUCTURE OF THE DISTRICT.

The surface of Brittany consists of sedimentary and eruptive rocks of Palæozoic age; the beds are much disturbed, and their outcrops form long, narrow bands, which are seen following the strike across the whole country in a west to east direction.

These great tectonic lines were determined by an important folding movement of Carboniferous age; but their formation had been prepared beforehand during a long series of geological epochs. This is proved by the coincidence of these lines with the former basins of deposit, with the difference of facies, the transgressions of the strata, and with the alignment of the successive intrusions of the deep-seated magmatic masses.

The fundamental structure of Brittany is to be assigned to the Carboniferous period. But the ruins only now remain; the relics of the ruined structure appear to us eroded by the secular action of atmospheric denudation. All the anticlinal arches have been swept away by the irresistible action of time. The synclinal depressions alone remain for our investigation—silent witnesses of the great power of the mechanical deformation which folded, strained, and fractured the rocks of the district.

The synclinal troughs, twenty-four of which are traced on the detailed map of Brittany, no longer preserve the simple symmetrical V-shaped form; they are reduced to deep and narrow unsymmetrical depressions, into which the beds slowly descended at the time when the crust was contracting. The

beds thus buried and preserved in these depressions are, as a rule, specially broken and crushed on their borders, where the greater faults of the country are found; in the centre of the synclines the beds show a uniform dip, and are, moreover, traversed by subordinate faults, which break up the land into a series of parallel inclined "blocks" or lamellæ.

The analysis of all the earth movements, of which traces have been preserved in Brittany, shows that they are related to one and the same continuous lateral pressure. This pressure acted in the same direction during the whole of the Palæozoic period on a zone of the earth's crust which was slowly subsiding.

For REFERENCES to the LITERATURE see *Bull. Geol. Soc. France*, ser. 3, t. xiv, 1886, and *Ann. Soc. Geol. du Nord*, vol. i to xxvii, Lille.

VISIT TO THE MUSEUM OF MR. W. H. HUDLESTON, M.A., F.R.S.

SATURDAY, MARCH 11TH, 1899.

(*Report by* PROF. J. F. BLAKE, M.A., F.G.S.)

THE members of the Association to the number of about thirty-five met in Mr. Hudleston's Museum at 3 p.m. They much regretted to find that their host was unable to be present to receive them personally. He had, however, made all arrangements by which the members might be enabled to see his collection at their pleasure.

Mr. Blake mentioned the departments in which the collection was especially rich, and then asked Mr. Semmons, who happened to be present, to demonstrate the minerals, which he kindly did, pointing out that the collection contained a number of specially fine examples of Cornish minerals obtained while the mines were in work, but now no longer to be had. After a short time spent on these, the drawers containing the materials for Mr. Hudleston's monograph on the Inferior Oolite Gasteropoda were brought out one by one and replaced, the points of interest in each being demonstrated by Mr. Blake and Mr. Newton as the drawers passed round. In this way the Members were able to appreciate the great bulk of the material on which that work was founded, a large proportion having been collected by Mr. Blomfield, who was present to show the collection. The specimens from the Great Oolite and a series of estuarine forms from a new locality were in a similar way examined.

Afterwards the company gradually transferred themselves from the Museum to the drawing-room, where, after acceptable refreshment, a vote of thanks, proposed by Mr. Newton, was heartily accorded to Mr. and Mrs. Hudleston for their kindness, and to Prof. Blake and Mr. Semmons for their interesting demonstration.

EXCURSION TO SEATON, SIDMOUTH, BUDLEIGH SALTERTON, AND EXETER.

EASTER, 1899.

Directors: HORACE B. WOODWARD, F.R.S., F.G.S., AND W. A. E. USSHER, F.G.S.

Excursion Secretary: BEDFORD McNEILL, A.R.S.M., A.M.I.C.E., F.G.S.

(*Report by* THE DIRECTORS.)

I.—SEATON.

By H. B. WOODWARD.

TWENTY-EIGHT years ago, Prof. James Buckman and Mr. J. Logan Lobley conducted an excursion of the Geologists' Association to the Yeovil district, and spent a short time on their fourth

and last day along the cliffs east of Seaton.* It seems strange, however, that forty years should have elapsed since the foundation of this Association before any expedition was made to the South Devon coast between Seaton and Exmouth, with its fringes of Blackdown Beds and its famous pebble-bed of Budleigh Salterton.

In 1889 an excursion was made to Lyme Regis, under the guidance of the present Director, and the members then advanced as far as the eastern portion of the Great Landslip.† It was now planned to continue the exploration from the Landslip westwards to the mouth of the Exe.

On Thursday evening, March 30th, the members of the party, which numbered nearly forty, arrived at the Royal Clarence Hotel, Seaton. On *Friday*, *March 31st*, the members started at 9 a.m. along the esplanade to Axmouth Bridge, where the Director pointed out that the trend of the beach turned the outlet of the river eastwards, and had been the means of choking the harbour of the once flourishing little fishing-town. At the close of the last century, a large tract of salt marshes extended above Axmouth, but these had been drained to the advantage of the neighbourhood. In far earlier times, when the river was more potent in action, spreads of valley-gravel were laid down, and from these at Broom, in the parish of Hawkchurch, above Axminster, some fine palæolithic implements, fashioned from Upper Greensand chert, had been obtained. Remains of Mammoth had been found in the Sid Valley, further west.

The party now proceeded by Squire's Lane to the lime-kiln beyond the Coastguard Station, where the Middle Chalk, zone of *Rhynchonella cuvieri*, had been noted by Mr. A. J. Jukes-Browne. This division cropped out along the 300 ft. contour-line. Several specimens of *Inoceramus mytiloides* and poor examples of the characteristic *Rhynchonella* were obtained.

Passing on through Barn Close and Stony Close Lanes, a pleasant walk over the grassy Chalk-plateau, here, in places 400 ft. high, led to the western end of the Great Landslip at the Bindon Cliffs. The view eastwards through the chasm was grand and striking, the slipped masses of Chalk and Greensand forming a platform about 100 ft. lower than the cliffs from which they had broken away. As some account of this Great Landslip, which happened at Christmas, 1839, has already been published by the Association,‡ no particular description need now be given.

Leaving the chasm, the members proceeded a short distance westwards along the brow of the cliffs and descended by a footpath to the shore a little west of Culverhole Point. Here in the

* *Proc. Geol. Assoc.*, vol. ii, p. 250.
† *Ibid.*, vol. xi, p. xxvi.
‡ *Ibid.*, vol. xi, p. xliii.

low cliffs fringing the beach a fine section of the Rhætic Beds was exposed. On the west side, and indeed from the mouth of the Axe eastwards to near Culverhole, the high cliffs are formed of Chalk and Greensand, resting on a foundation of the red and variegated Keuper Marls. These marls are bent into gentle undulations, and they are displaced by several faults which cut the cliffs obliquely and sometimes nearly parallel with the coast. Near Seaton and Branscombe they contain gypsum and pseudomorphous crystals of rock-salt. Towards the top of the red marls there is a layer of hard pale-grey or buff banded marl with dark clayey streaks, which marks the commencement of the gradual change of conditions into the succeeding Rhætic series.

The strata dip eastwards at an angle of about 5 deg., and within a short distance the entire Rhætic series is exposed. These beds again are displaced by slight faults, some of which, however, appear to be due to landslipping. Resting on the White Lias, as had been observed by Mr. Jukes-Browne, there were some pale-grey clays belonging to the base of the Gault, and it is interesting to note that Conybeare had in 1840 referred to a possible trace of Gault near Culverhole.*

The section at Culverhole was as follows:

			ft.	in.
RHÆTIC BEDS	WHITE LIAS	Thin-bedded white limestones, here and there wedge-bedded, and with concretions or pebbles of compact limestone in the lower part ... ... about	15	0
		Impersistent masses of rudely arborescent Cotham Stone ... ... about	0	8
	BLACK SHALES	*Avicula-contorta* Shales with bone-bed at base ... ... about	18	0
TEA-GREEN MARLS (PASSAGE-BEDS FROM RHÆTIC INTO KEUPER).		Green marl	10	0
		Alternations of pale greenish and creamy marls with hard bands of marly limestone and dark grey and black clays ...	20	0
	KEUPER	Dark, light-grey, green, and red cuboidal marls ... ... Hard layer of pale-grey or buff banded marl with dark clayey streaks	15	0
		Green, grey, and red marls		
		Red and variegated marls		

The Tea-green marls form a persistent band on top of the red and variegated marls, but with no definite plane of division separating them. The change in colour from the mass of red marls with their irregular mottling, to the mass of grey, green, and almost black marls and clays, indicates a gradual change of sedimentary conditions, and not a change due to subsequent chemical action. The Red marls (as is well known) retain their distinctive colour at the surface, while the Tea-green or Grey marls possess the same colour at a depth below ground as proved in borings.

* "Memoir on Landslips," p. 2.

The hard bands in the red and grey marls may be sedimentary limestones.*

At Axmouth the occurrence in the Tea-green marls of the bands of dark grey or black clay foreshadow the Black *Avicula-contorta* shales, but they do not in this locality appear to be fossiliferous. A bone-bed has, however, been met with in the green marls, 4 ft. below the Black Shales at Gold Cliff; and elsewhere, as at Watchet, fossils have been rarely obtained at such horizons. The occurrence also in Warwickshire of *Acrodus keuperinus*, A. S. Woodw., and *Semionotus brodiei*, Newt.,† as well as of *Goniomya* and other lamellibranchs,‡ is significant that conditions suitable to life came on somewhat irregularly during the Triassic period in the British area. Hence it is that this Tea-green marl series, which was grouped with the Rhætic Beds by Messrs. H. W. Bristow and R. Etheridge, is in some localities more closely allied with the Rhætic Beds, and in other localities with the Keuper Marls.§ As Edward Forbes pointed out, the Red marls were probably formed in a great inland sea, like the Aralo-Caspian, during the later stages in whose history there were influxes of the sea, bringing in the Rhætic fauna, while the Liassic fauna overspread the area during subsequent depression.

The Axmouth Bone-bed lies at and near the base of the Black Shales. The rib of a Reptile was observed by Mr. E. T. Newton near the base of the Shales, while numerous Fish-remains, including *Acrodus*, *Gyrolepis alberti*, Ag., *Hybodus*, *Lepidotus*, and *Sargodon ?* were identified by him from specimens obtained in crevices of the Green Marl at the base of the Black Shales.||

Numerous fossils were found in the Black Shales, including the characteristic *Avicula contorta*, Portl., also *Anatina præcursor*, Quenst., *Cardium rhæticum*, Mer., *Hinnites*, *Modiola*, *Pecten valoniensis*, Defr., and *Pleurophorus*.

Leaving Culverhole, the party retraced their steps along the footpath to the top of the cliffs, and proceeded westward along Haven Cliff (300 ft.) to the old quarry south-east of the Coastguard Station, where the junction of the Upper Greensand with the Lower Chalk was exposed. The junction was by no means well defined, but the basement portion of the Chalk, or so-called Chloritic Marl, which contains quartz grains and grains of glauconite, and rests on brown sandstones (Upper Greensand), yielded the following fossils, which were identified by Mr. E. T. Newton:¶

* See H. B. W., "Memoir on Lias of England and Wales" (Geol. Survey), p. 31.

† E. T. Newton, *Quart. Journ. Geol. Soc*, vol. xliii, p. 537.

‡ R. B. Newton, *Geol. Mag.*, 1893, p. 557.

§ See H. B. W., *Proc. Geol. Assoc.*, vol. x, p. 529.

|| See also Egerton, *Proc. Geol. Soc.*, vol. iii, p. 409.

¶ See also Meyer, *Quart. Journ. Geol. Soc.*, vol. xxx, p. 393; Barrois, "Recherches sur le Terrain crétacé," 1876, p. 75; Jukes-Browne, *Geol. Mag.*, 1877, p. 361; Meyer and Jukes-Browne, *Ibid.*, 1894, p. 494.

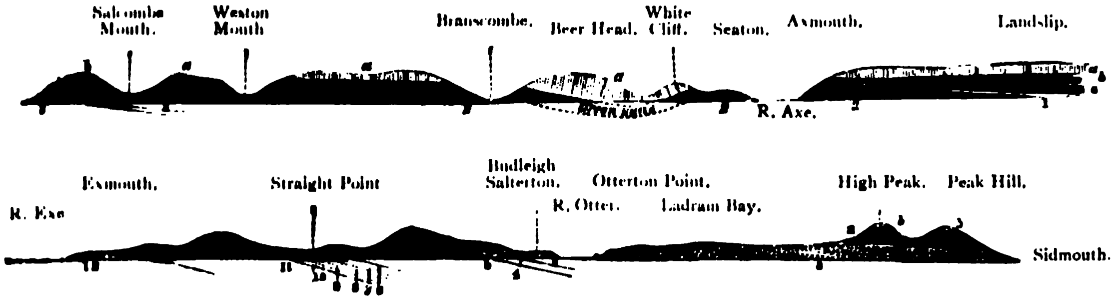


FIG. 1.—SECTION ALONG THE SOUTH-DEVON CLIFFS FROM EXMOUTH TO THE LANDSLIP NEAR AXMOUTH, WEST OF LYME REGIS. (W. WHITAKER, *Quart. Journ. Geol. Soc.*, vol. xxi., p. 155.)

a. Chalk.
b. Upper Greensand.
c. Lower Lias.
1. Rhætic Beds.
2. Dark red marl. Upper Marls. } Keuper.
3. Red sandstone. Upper Sandstones } Keuper.
4. Pebble-bed. [Bunter.]

5. Dark red marl.
6. Red sandstone
7. Dark red marl
8. Red sandstone
9. Dark red marl.
10. Red sandstone.
11. Dark red marl.
(5–11: Lower Marls.)
12. Red sandstone and breccia. Lower Sandstones, etc.
(5–12: [" Permian."])

Ammonites (*Acanthoceras*) *mantelli*, Sow.; *Am.* (*A.*) *navicularis*, Mant.; *Am.* (*A.*) *rotomagensis*, Brong.; *Nautilus*, sp., *Pleurotomaria?* (cast), *Exogyra*, sp., *Lima hoperi*, Sow.; *Pecten asper*, Lam.; *Pecten (Neithea) quinquecostatus*, Sow.; *Rhynchonella dimidiata*, Sow.; and *Discoidea subuculus*, Leske.

Returning to Seaton, the members (after lunch) proceeded along the West Walk by cliffs of Red (Keuper) Marl to the foot of White Cliff. Here the cliffs, which rise to a height of about 250 ft., show a grand section of Chalk and Upper Greensand, resting on the Red Marl. Owing to a syncline, the Lower and also the Middle Chalk descend westward to the sea-level, and rise again beyond Beer Head. At White Cliff the beds are faulted against the Red Marls on the east, a fault not clearly shown in section owing to the talus, but proved by the flat bedding of the marls in the cliffs and on the foreshore east of the fault, whereas the Cretaceous beds on the west are tilted up. The Greensand is here conspicuously divided into an upper cherty series, and a lower series of greensands which yield many of the fossils of the Blackdown Beds (zone of *Ammonites rostratus*). At the very base of the Greensand (as observed by Mr. Jukes-Browne) there are greenish clayey beds which belong to the zone of *Ammonites lautus*. The chert-beds, as observed by Mr. Meÿer, yield *Pecten* (*Neithea*) *quadricostatus*, *Exogyra columba*, etc., and they are separated from the Chalk above by 20 ft. or more of buff-coloured and glauconitic sandstone.

It was pointed out that the Chalk of this region was broadly divided as follows:

UPPER CHALK	zone of Micrasters
	,, ,, *Holaster planus*
MIDDLE CHALK	,, ,, *Terebratulina gracilis*
	,, ,, *Rhynchonella cuvieri*
LOWER CHALK	including Chloritic Marl.

Information kindly furnished by Mr. A. J. Jukes-Browne enabled the members to readily see the successive zones which have been identified in the Chalk from the summit of White Cliff to the shore at Beer. Ascending White Cliff by the foot-path near the fault, and passing over the higher part of the hill, the members descended to a bluff known as Annis Knob. Here a mass of remarkably nodular chalk was seen, the nodules being some of flint with thick white siliceous crust and a tiny nucleus of black flint, while a large number were composed of more or less siliceous chalk.

A prominent band of black flints near the middle of the bluff was taken by Mr. Jukes-Browne as a convenient divisional plane between the zones of *Micraster cortestudinarium* and *Holaster planus*. Not many fossils were found in the exposed face of Chalk, but it was understood that Dr. A. W. Rowe and Mr. C. D. Sherborn had not long previously made an

exhaustive search. The Micraster beds above the prominent flint-band yielded *Terebratula carnea*, Sow., *Terebratulina striata*, Wahl., *Rhynchonella reedensis*?, Eth., and a plate of *Cidaris*. From the zone of *Holaster planus*, in which thin layers of hard compact chalk (Chalk Rock) were noticeable, there were obtained the characteristic *Holaster*, also *Micraster breviporus*, *Cyphosoma*, and *Terebratula carnea*. These and other fossils were identified by Mr. Newton. Descending to the main portion of the cliff which forms the eastern side of Beer Harbour, it was pointed out, on the evidence of Mr. Jukes-Browne, that the Chalk which forms the upper part of this cliff bordering the sloping pathway that leads to the beach, belonged to the Middle Chalk zone of *Terebratulina gracilis*, about 80 ft. thick, beneath which, and bordering the shingle beach was the zone of *Rhynchonella cuvieri*, about 40 ft. thick. Many small specimens of *Terebratulina gracilis*, Schl., var. *lata*, Eth., were obtained from the zone of *T. gracilis*. The lower beds belonging to the zone of *R. cuvieri*, including the representative of the Beer Stone, formed the headland with a natural archway on the eastern side of Beer Harbour; while reefs of the Lower Chalk extended beneath and formed the point, resting on a floor of the Upper Greensand, which gradually rose eastwards under White Cliff. It was mentioned that a manufacture of gun-flints was formerly carried on at Beer Head.

Beer Village (which takes its name from the Norse *byr*, signifying an abode or farmstead) rests on an inlier of Upper Greensand. After taking tea in the village, the members proceeded along Quarry Lane to the famous Beer Stone quarries, about a mile distant. On the north side of the lane there is an immense quarry, about 80 ft. in depth, in the Middle Chalk, with tunnels at the base, where the Beer Stone has been more recently worked, the upper strata having been quarried for lime-burning. These comprise the zones of *Terebratulina gracilis* and *Rhynchonella cuvieri*.* On the south side of the lane the stone had been worked underground from a very early period. The levels have been driven in nearly along the 300 ft. contour.

The Managing Director of the Beer Freestone Co., Mr. A. W. Oakley, had most courteously arranged that both new and old workings, which extend long distances underground, should be lighted with candles, and the members were conducted through the many and devious ways by Mr. E. Terrell.

The tunnels are supported by masses of the freestone, aided here and there by timber. The stone is sawn out *in situ*, and blocks from six to eight tons are obtained. It is comparatively soft when taken from the workings, but hardens on exposure. From its uniform texture and close grain it is admirably adapted for carving, and especially for inside decorative work.

* Jukes-Browne, *Quart. Journ. Geol. Soc.*, vol. liv, p. 242.

It has, however, been used with success for outside work in many of the neighbouring churches, and it is now being employed in the building of the Roman Catholic Cathedral at Norwich.

The rarity of fossils, of course, has been an advantage to the Beer Stone. Mr. Terrell exhibited a few specimens which he had obtained from it, and they included *Nautilus*, *Inoceramus mytiloides*, Mant., *Terebratula semiglobosa*, Sow., *Echinoconus subrotundus*, Mant., and *Lamna appendiculata*, Ag.

Fitton many years ago thought that the Beer Stone might represent the Totternhoe Stone,* but it is now known to be on a higher horizon.

After a hearty vote of thanks to Mr. Oakley and Mr. Terrell the party were driven back to Seaton.

II.—SIDMOUTH.

By H. B. Woodward and W. A. E. Ussher.

April 1st.—Leaving Seaton soon after 9 a.m., the members were driven along the new Beer road and across the plateau of Chalk and Upper Greensand, by Stovar Long Lane to Holy Head (419 ft.), and past Hangman's Stone (479 ft.), to the top of Salcombe Hill (557 ft.). Here, alighting from the vehicles, they took the track leading by South Down Farm towards the brow of the cliffs. Attention was arrested by some large blocks of siliceous breccia, and these were presumed to be relics of former Eocene deposits which once spread across the area, and to which further reference was subsequently made (see p. 151). Long ago Mr. Godwin-Austen remarked on the resemblance of these blocks to grey-wethers,† and it was mentioned that rolled portions of the rock picked up on Sidmouth beach have been polished and sold as Sidmouth pebbles. The included fragments were angular, but, as Mr. Clement Reid had shown, the materials forming the Bagshot gravels were more and more angular as they were traced westwards.

It was not possible, owing to the mist, to see the stretch of coast-line east of Sidmouth, but it was remarked that there was evidence of two great plains of erosion (or peneplains), the one formed by the denudation of the Oolites, Lias, and New Red series, on a fairly level surface of which were laid down the Upper Cretaceous strata; and the other by the denudation of the Gault, Upper Greensand, and Chalk, on which were remnants of Eocene (Bagshot) strata, more or less modified or re-arranged in places by subsequent subaërial agencies. Reference was also made to

* *Trans Geol. Soc*, ser. 2, vol. iv, p. 234.

† *Ibid.*, ser. 2. vol. vi, p. 447.

Buckland's early observations on the formation of valleys in this district.* The President (Mr. Teall) referred to the contrast between the two earlier unconformities which formed such a marked feature in the geology of the West of England. The "continental" New Red Sandstone formation rested on an uneven land-surface composed of folded Culm and other rocks; the marine Upper Cretaceous rested on a flat plain of denudation. These two uncomformities forcibly reminded him of the two much older unconformities of the North-West of Scotland, where the "continental" Torridonian rested also on a surface which had been carved into hill and valley, and the marine Cambrian on what was once a flat plain.

On nearing the brow of the cliffs on Salcombe Hill the members were met by Mr. Ussher, who now undertook the direction.

Mr. Ussher said they were about to visit only a small part of the finest and most continuous New Red Sandstone section in England, if not in the world—one which should be taken as the basis for classification. He deprecated any classification founded only on the coast section, magnificent as it was. In that section the Lower sands and breccias came on with a fault at Exmouth, and the contemporaneous traps (a probable correlative of the Permian melaphyres of Germany) were not represented. The general downward succession was: Upper Red Marls, Upper Red Sandstone, Pebble-beds, Lower Red Marls and Marls with Sandstone, Lower Sandstone and Breccia, Breccia and Conglomerate, Watcombe Clay. They would not see anything below the upper part of the Lower Sandstone and Breccia on the coast towards Exmouth.

Descending by the zig-zag path to a foot-bridge over the Sid at Sidmouth, the members walked a short distance eastwards along the shingle, the outlet of the river being at the time entirely choked by the beach.

Mr. Ussher showed the conformable nature of the junction between the Keuper Marls and underlying sandstones, scarcely disturbed by three small faults. In the occurrence of occasional thin flaggy beds of sand- and mud-stone in the lower part of the Marls, the equivalent of the Waterstones of the Midlands was recognised.

The President thought that the red colour of the formation was mainly due to the subaërial decomposition of rocks containing ferriferous compounds, under conditions similar to those prevailing at the present day in India, the Southern States of eastern North America, Brazil, and parts of Africa, in short, to what might be termed the lateritic type of decomposition. Under this mode of decomposition the iron becomes oxidized, and deposited as a coating on the grains of quartz and other un-

* *Trans. Geol. Soc.*, ser. 2, vol. i, p. 94.

decomposed minerals. The red material thus produced would mantle the slopes, fill up the hollows, or be spread out as flat fans over the low ground by torrential action. It would also be deposited in lakes, lagoons, or seas. In the presence of decomposing organic matter the ferric oxide would be reduced, the red colour would disappear, and the iron would take the form of a sulphide or carbonate. Thus the change in the colour seen near Axmouth at the junction of the Rhætic and Keuper was directly connected with the absence of fossils from the latter and their abundance in the former deposit.

After visiting Sidmouth, the members assembled at the Chit Rock at the western end of the Esplanade, and then proceeded by the road and footpath west of Sea View, and descended by the wooden staircase to the beach on that side of the Chit Rock. Here a composite fault was seen cutting off the sandstones, and throwing down the marls on the west.

From this point the cliffs rapidly rise westwards from about 50 ft. to 500 ft. at Peak Hill, where there is a capping of Upper Greensand and gravel, while inland the ground rises over 600 ft.

Farther on Mr. Ussher called attention to the outcrop of the sandstones on the beach, and below Windygate he showed that the junction was not a definite plane, inasmuch as the lowest beds of the marls are more or less sandy, and pass imperceptibly into sandstone, so that viewed from the beach the junction-line, without any apparent change, seemed higher up the cliff in some places than in others. On the beach he pointed out a calcareous concretionary bed denoting the outcrop of the upper part of the conglomeratic beds in which, at Otterton Point, Mr. H. Johnston-Lavis found *Labyrinthodon*, and the late Dr. H. J. Carter many traces of bones.* Mr. Ussher showed that the concretionary character was not restricted to an absolute horizon.

Mr. Newton here illustrated some remarks by the exhibition of a jaw of *Hyperodapedon*, a lacertilian reptile which had been obtained thirty years ago by Mr. Whitaker, and was the first fossil (of the period) found in the New Red rocks of this region.

The grand cliffs of Red Marl below Peak Hill attracted attention, the deep rain-channels cut in the marls giving to the scene a cañon-like appearance.

Ascending by a trackway to the Windygate path (350 ft.) west of Peak Hill, the members observed traces of pseudomorphs of rock-salt in the green, shaly sandstone. After a halt for lunch, they proceeded along the brow of the cliffs to Ladram Bay. The cliffs, which are here about 50 ft. high, were seen to consist of Red Marls on Sandstones, faulted in several places, and worn away into picturesque bays with a prominent stack known as the Hern Rock.

Ladram Bay, which contains a natural arch on the north

* *Quart. Journ. Geol. Soc.*, vol. xliv, p. 318.

side, was then visited. Mr. Ussher here drew attention to the false-bedded character of the sandstone, and to the local occurrence of a network of calcareous concretions, best seen between Ladram Bay and Budleigh Salterton. This was suggestive of the Lower Keuper Dolomit of Germany.

The party then proceeded through a deeply-cut lane in the Red Sandstone, towards Otterton, visiting a brick pit in an outlier of Keuper Marls, which Mr. Ussher showed by the maps to owe its position to the repeating faults on the north side of Ladram Bay.

After passing through the pleasant village of Otterton, and crossing the river Otter, which was bordered in places by red sandstone cliffs, the Members reached East Budleigh Station, and took train to Exeter, for the Rougemont Hotel.

III.—BLACKDOWN.

By H. B. Woodward.

April 2nd.—After breakfast a small party left the Great Western Railway Station (St. David's), for Cullompton Station, and then walked by Kentisbere Moor, Kentisbere, Moneyland, and France to the Puncheydown or Poncheydown Inn on Blackdown, here about 750 ft. above sea-level. A few fossil sponges and some echinoderms and other fossils were purchased at the inn.

Afterwards a whetstone level, N.E. of the post office on Blackborough Common, the only working now open, was visited. The stone used for the manufacture of the scythe-stones, whetstones, or Devonshire "Batts," occurs irregularly in the greenish sands, the good stone being sharply jointed and occurring in larger and smaller masses together with a few irregular and fantastically formed nodules of cherty sandstone.

The stone is soft when taken from the workings, and it can then be readily shaped and afterwards rubbed down (with water) into proper form. On drying it becomes very hard. Fitton, who gave an excellent account of the strata, remarked that formerly a large proportion of the scythe-stones used in England were obtained at Blackdown.* Even now there is a demand greater than the very limited supply which can be obtained from one working, but the useful beds are said to be nearly exhausted. They occur from 15 to 25 ft. below the surface, and have been worked along the steep scarp of the hills. The whetstone-beds occur beneath a head of cherty detritus, and the beds themselves are about 25 ft. thick, resting on 20 or 30 ft. of yellow sandrock.

* *Trans. Geol. Soc.*, ser. 2, vol. iv, p. 234.

The whetstone rock as described by Dr. Hinde "is filled with sponge-spicules and their empty casts, cemented together by chalcedonic silica. Quartz-sand and glauconite grains are also present, but no calcite, and only a small amount of mica. . . . The spicules are chiefly of chalcedonic silica; some appear to be partly of crystalline silica; . . . the cementing silica, which renders this material suitable for whetstones, is derived from the solution of the spicules, and the chalcedonic silica, which has replaced the calcite of the molluscan shells in the same beds, may be attributed to the same source.*

To the Rev. W. Downes we have been indebted for our latest information about the Blackdown Beds and their fossils.† He pointed out that "a good deal of confusion has arisen through the mingling together in collections of specimens from other Greensand localities with Blackdown fossils," and he observed that "No true Blackdown fossil is calcareous."

At Salcombe Hill and some other localities similar silicified fossils are to be found.

Among the more abundant of the Blackdown fossils are: *Siphonia tulipa* (*S. pyriformis*, Goldf.), *Vermicularia concava*, Sow, *Rhynchonella*, *Exogyra conica*, Sow., *Gervillia anceps*, Desh., *Cucullæa carinata*, Sow., *Pecten milleri*, Sow., *Pectunculus umbonatus*, Sow., *Trigonia scabricola*, Lyc., *Cyprina angulata*, Flem., *Aporrhais parkinsoni*, Mant, *Dimorphosoma calcarata*, Sow., *Turritella granulata*, Sow., and *Ammonites varicosus*, Sow. Examples of many of these were obtained.

The Blackdown Beds were regarded by Godwin-Austen and Daniel Sharpe as representing a more or less littoral facies of the Gault;‡ and it is now known that they represent the Upper Gault, zone of *Ammonites rostratus*.

Proceeding to the highest point of Blackdown, 897 feet, the members had a good view of the Wellington Monument, and they then returned by Poncheydown gravel pit and Newcombe Common to the lane, by Saint Hill and Hollis Green. Passing through Kentisbere, and noting a section of the Pebble-beds on the horizon of those of Budleigh Salterton, they proceeded to Cullompton Station by Kentis Ford and Long Moor, taking a peep at the rough, cherty gravel which here and there overlies the Lower Red Marls in this area. It was mentioned that the Rev. W. Downes had obtained a Palæolithic implement from the gravel on Kentisbere Moor, near Kentisbere,§ where for several years he resided as curate. This enthusiastic worker afterwards became Rector of Combe Raleigh, near Honiton, and died in 1886.

* *Phil. Trans.*, 1885, p. 421.

† *Trans. Devon Assoc.*, vol. xii, 1880, p. 420, and *Quart. Journ. Geol. Soc.*, vol. xxxviii, p. 75.

‡ *Quart. Journ. Geol. Soc.*, vol. vi, p. 472; vol. x, p. 185.

§ *Geol. Mag.*, 1870, p. 480.

IV.—BUDLEIGH SALTERTON AND EXMOUTH.

By W. A. E. USSHER.

April 3rd.—The members started from the Queen Street Station, Exeter, by the 9 a.m. train to Exmouth, where vehicles awaited them, and they were driven through a pleasant hilly country to the Rolle Arms Hotel, Budleigh Salterton. On the way a pit in the Triassic Pebble-beds was passed.

On leaving the hotel the attention of the party was called to the view of Otterton Point and Budleigh Salterton Parade. At Otterton Point the conglomeratic beds in the Upper Sandstone, the outcrop of which had been seen in Ladram Bay, occupy the base of the cliff for about 10 ft.; the cliff by the Budleigh Salterton Parade is formed of sandstones underlying the conglomeratic beds in which the irregular calcareous character is well shown. The Director showed the impossibility of making any

FIG. 2.—THE CLIFF WEST OF BUDLEIGH SALTERTON, DEVONSHIRE. (W. VICARY, *Quart. Journ. Geol. Soc.*, vol. xx, p. 283.)

d. Gravel. *c.* Red sandstone. [Keuper] *b.* Pebble-bed. [Bunter.] *a.* Lower red marl. [" Permian."]

N.B.—The grouping given in brackets in Figs. 1 and 2 is that adopted on the Index Map of the Geological Survey.

division, even an arbitrary one, in the sandstones; and having previously shown their intimate relation to the overlying marls, he claimed them as Lower Keuper.

The cliffs rise rapidly from about 30 ft. at the "Rolle Arms" to over 400 ft. at West Down Beacon, the scarp of the Pebble-beds. For a short distance the sandstones were seen to be covered with a thick bed of pebble-gravel, a downwash from the higher exposed outcrop of the Budleigh pebble-bed. (See Fig. 2.)

The pebble-beds which crop out on the beach from under the sandstones at a short distance from the commencement of the

cliff are about 70 ft. thick; three small faults occur in them. Their relations to the overlying sandstones are perfectly conformable, and lenticles and beds of sandstone occur in them, rendering it very difficult, in the local failure of pebbles, to distinguish the one horizon from the other. Although the Director had often noticed that the sand replacing Pebble-beds contained rounded grains, whilst the overlying sands were more or less angular and finer, sufficient observations had not been made to establish a general rule. In the sandstones, pebbles occasionally occurred at some distance above the pebble-beds, an instance of which was afforded at the commencement of the cliff. In this intimate connection, and in tracing the horizons northward throughout their extension, the Director could not see his way to classify these beds with the Bunter; and as he considered that the sandstones were not older than Lower Keuper, he regarded the pebble-bed (which passes into a hard conglomerate with calcareous cement in the Wellington and West Somerset area) as the base of the Keuper. The pebble-beds rest on about 500 ft. of marls of similar character to the Keuper Marl, and mottled with small greenish spots. The junction which, in consequence of slip, was not well exposed on the beach, had furnished him with no proof of unconformity, either as regards dip or erosion. The very trivial irregularities in the exact line of junction were such as he had often observed in the New Red rocks (for instance, in the Lower New Red Sand and Breccia cliffs bounding Oddicombe beach), and appeared to be slight signs of contemporaneous erosion. (See remarks by Mr. Clayden, p. 148.) He, however, regarded the base of the pebble-beds as an important evidence of physical change, such as might be occasioned by the destruction of a barrier between deposits forming under lacustrine conditions and the then existing coast, whereby pebbles would be swept northward over lacustrine marls. Mr. Ussher stated that the Devonian and Silurian quartzite pebbles so abundant on the coast were more or less gradually replaced by pebbles of more local origin, as the bed was traced northward beyond Uffculm.

Mr. Newton here made some remarks on the fossils found in the pebbles, which had been submitted by Mr. Vicary to the late Mr. Davidson for identification. From specimens collected, Mr. Newton identified *Orthis budleighensis*, Dav., *Lingula lesueuri*, Rou., and worm-burrows (*Trachyderma*?).

Mr. Woodward remarked on the fact that similar quartzites occurred in the Bunter pebble-beds of the Midland counties. Prof. Lapworth, who had so lately given an account of these, had pointed out that there might be quartzites of pre-Cambrian, Cambrian, Ordovician, Silurian, Devonian, and Carboniferous ages.* There were at any rate Ordovician pebbles with *Orthis*

* *Proc. Geol. Assoc.*, vol. xv, p. 382.

budleighensis, and also *Lingula lesueuri* (of the Grès Armoricain); and Devonian pebbles with *Spirifer verneuili* and *Homalonotus*. Whether these Midland pebbles were accumulated in areas wholly marine, or wholly fluviatile; whether they were derived in part from earlier conglomerates, or were entirely shaped in Triassic times; whether they came from the north or south, or from local rocks, were questions put (but not answered) by Prof. Lapworth: and they might be put at Budleigh Salterton.

The President pointed out that not only were fossils of the Budleigh Salterton pebbles found in the Bunter pebbles of the Midland counties, but that pebbles of schorl-rock, similar to those so abundant on the beach before them, were also found in the Bunter of Nottinghamshire. He had recently examined two pebbles collected by Mr. H. W. Monckton from the Bunter of Nottinghamshire, and they were practically identical with contact-rocks occurring in the West of England. It should be remembered that the so-called schorl-rock included altered granites, vein-stuff, and metamorphosed shales, impure cherts and grits.

On the way to Straight Point, the occurrence of a bed or beds of sandstone in the marl in one spot was observed. At Littleham Cove, near Straight Point, the Director showed that the marls were cut off by a fault (downthrow about 150 ft. to north), against marls on sandstone and sand, false laminated, and partly brecciated with nearly angular hard, dark quartzite stones. The sand grains are often coarse and well-rounded, characters both as regards brecciation, false lamination, and rounded grain, commonly met with in the sandstones and breccias of Langstone Point, Dawlish, etc. He was uncertain whether to refer the Straight Point sandstones to the upper part of this Lower series, or to a passage series in the lower part of the Marls. He had not visited the section for many years, and the lower part was not then so well exposed as on the present occasion. From what he saw before him, he should have no hesitation in considering the Straight Point sandstones as the upper part of the series, cut out by a fault in Exmouth Shrubbery. Calcareous concretionary beds (apparently dolomitic), were observed in the Straight Point sandstones.

On the other side of Straight Point, proceeding to Exmouth, about two miles distant, the way lay along a pleasant expanse of sands, with reefs of sandstone. The Director pointed out numerous faults affecting marls with thick beds of sandstone which he had mapped over twenty years ago, and which had then seemed to him to have the effect of placing the Straight Point sandstones at least 200 ft. above the base of the marls; that appearance was confirmed by the present inspection, and he begged leave to recall the remarks he had made at the fault on the other side of the Point as to placing the Straight Point sandstones at the base of

the marl series. The Director further remarked on the similarity cf the sandstone beds in the marls to Bunter sandstones in Germany, a similarity noticed by Baron von Reinach in 1891, on a visit to this coast. After passing Orcombe and Rodney Points, the members reached Exmouth, and visited the Shrubbery or Plantation at Beacon Hill, where sandstones, brecciated with numerous fragments of similar character to those at Straight Point, *but undoubtedly belonging to the Lower series,* are exposed, being faulted against the marls with sandstones. This similarity showed the intimate connections of the marl series below the pebble-beds with the Lower series of sands and breccia.

From Exmouth the train was taken to Exeter.

After dinner votes of thanks were accorded to the Directors, and great indebtedness was then expressed to two resident workers at Exeter, Mr. Arthur W. Clayden, F.G.S., and Mr. F. G. Collins, F.G.S., who had largely added to the success of the excursion by their local knowledge. Regret was expressed at the absence, through the infirmities of age, of Mr. William Vicary, F.G.S., whose life-long labours on the geology of the country around Exeter were so well-known and appreciated.

Mr. Clayden then very kindly exhibited a series of lantern-slides; also his interesting models of ocean currents, and explained what a tremendous effect on the climate of the North Atlantic, and also on that of the South Atlantic, would be produced by any considerable submergence of Central America.

On exhibiting a photograph of the Budleigh Salterton pebble-bed, which showed the coarse pebbles resting on the underlying marls, Mr. Clayden remarked that this was the section referred to by Dr. Irving, and he now called attention to the markedly irregular surface of the marl, which certainly suggested erosion. When it had been remarked that the irregularity might be caused by a small fault, he had pointed out that many of the lines of pebbles were quite continuous across the section and showed no trace of faulting.

When showing some diagrams of the volcanic rocks of the Exeter district, Mr. Clayden remarked that the breccias and other rocks which accompanied and overlaid the lavas certainly seemed to have come from lofty hills lying somewhere to the west or north-west, probably the former; and it was reasonable to suppose that the lavas might have come from the same direction. Sir A. Geikie, in his great work on "Ancient Volcanoes of Britain," expresses the opinion that the vents are now buried under the New Red series. This would imply a flow from the east or north-east. None of the vents had yet been found. In the valley of the Teign, however, there were a large number of pipes, sills, and bosses, of a basic or intermediate type, many of them being intrusive into the contorted Culm-Measures, while the lava at Pocombe lies on the denuded edges of the same rocks. They occur a few miles west of the lavas, and it seemed worth while to inquire whether some of them might not be the actual sources of the Exeter traps. The lavas were much decomposed.

The President expressed the opinion that the decomposition of the Exeter traps was largely of New Red age, and that it represented what he had termed the lateritic type of decomposition. The destruction of the igneous rocks had contributed to the formation of the red beds.

A visit was now paid to the Devon and Exeter Albert Memorial Museum, under the courteous guidance of Mr. James Dallas, the curator. A brief inspection was made of the objects of natural history and art, and the members were afterwards conducted through the fine Free Library and the Technical and University Extension College.

V.—EXETER, DUNCHIDEOCK, AND GREAT HALDON.

By W. A. E. Ussher.

On *Tuesday*, *April 4th*, the members drove from Exeter, through St. Thomas', to Crossmead, and were then conducted along the road leading to Pocombe Bridge. Here a deep cutting showed the junction of the trap with the Culm-measure shales and grits, on the upturned edges of which it rests. The trap is mingled with a film of earlier New Red sediment at its base, doubtless caught up in the lava flow. In the Pocombe quarry, west of Crossmead, the trap was overlain by New Red sands. The thickness of the Pocombe trap is said by Mr. Vicary to be from 30 to 70 ft.

The President referred to the important paper by Mr. B. Hobson on the traps of the district. He himself was in doubt as to the name that should be given to the Pocombe rock. The felspar, to judge from the single specimen he had examined, appeared to be an alkali-felspar containing much potash. If so, the rock should not be called olivine-basalt. Olivine-trachyte would be more appropriate. Chemical analyses were absolutely necessary to determine the petrographical affinities of the Exeter traps, and the work would then not be easy, in consequence of the extensive alteration which had in most cases destroyed the ferro-magnesian constituents.

The party were then driven on to Ide (St. Ida's), whence they walked to West Town, where there are three patches of trap. West Town quarry, about a mile west of Ide, in the largest patch, showed indurated sand-beds near the surface, which, Mr. Ussher stated, were a common phenomenon, sometimes occurring in pipes or dykes, the infillings of cooling cracks, by subsequent sedimentation; sometimes as films, beds, or lenticles deposited in the interval between lava flows, by which they were subsequently indurated. These veins are occasionally dolomitic, often light red in colour, and mottled with round greenish spots. Colloquially Mr. Rutley and he used to refer to them as "Spottylite." Mr. Vicary had caused a pit to be sunk in the floor of the quarry to the New Red breccia with trap fragments, which Mr. Ussher inclined to regard as the earlier products of eruption mixed with the existing sediments. Mr. Teall pronounced the rock a quartz-basalt; he detected iddingsite in the trap-rock.

Walking from Ide (130 ft.) uphill to Markham Cross (nearly 400 ft.), the members were then driven by Dunchideock Bridge to the old quarry by the roadside at School Wood or Great Plantation, and there it was observed that quartz inclusions were less conspicuous in the trap-rock.

Proceeding in the vehicles to Great Haldon, passing near to

Belvedere (800 ft.), a glorious view was obtained of the Teign Valley and Dartmoor. Mr. Ussher gave a brief address, pointing out the eastern end of Dartmoor. He said they were looking from a fragment of the great Tertiary planing of the Cretaceous rocks, the eastern part of which they could see in the distant line of the Blackdowns. The Greensands of Haldon were severed from those of the Blackdowns by the excavation of the Exe Valley and its tributaries. They had seen near Seaton the Greensand resting on Rhætic Beds; at Salcombe and Peak and High Peak Hills on Keuper Marls; here, at Haldon, they found it resting on the lower beds of the New Red Sandstone, showing the overstep of the Cretaceous rocks. Between the New Red fringe of Haldon Hill and Dartmoor the lower hills and dales were composed of Culm-Measure shales and grits, with intrusive and perhaps contemporaneous masses of dolerite and some bands of tuff. When they considered that these Culm rocks had been compressed by the great post-Carboniferous movements into innumerable folds and contortions, and that subsequently they had suffered such great denudation, prior to the deposition of the New Red rocks, that the lower beds of that series rest on Lower and Middle Devonian at Torquay and Paignton, postulating the removal of the whole of the Upper Devonian and Culm rocks, they would readily grasp the tremendous gap in time between the Culm rocks and the New Red rocks, and understand why he stood out for the term New Red Sandstone as applied to the common character of the unbroken sedimentation in Devon of the Secondary rocks below the Rhætic Beds. There were slight traces of a plane of denudation in the formation of the New Red which may, to some extent, have determined the summits of the Culm-Measure highlands. But here on Haldon there was beneath them Greensand on the planed surface of the New Red rocks, themselves unconformable on the Culm-Measures. In conclusion, he would point out the thinning out of the Dunchideock trap mass on the slope below Haldon, allowing the overlying Breccia to rest directly on the Culm-Measures. Further south, trap is visible in one place only, near Whiteway House. There is no sign of it on the coast, and, but that it seems nearly certain that the horizon occurs at the base of the igneous boulder-bearing breccia of Teignmouth and Labrador Inn, we should lack the most reliable fulcrum for classification in this maximum development of the New Red rocks of the S.W. of England; as, from correspondences in rock type and in character of breccia, the correlation of the traps with the melaphyr zone or Söterner of Germany, and of the overlying breccia with the Wadern beds of the Upper Rothliegende, is by no means improbable.

Driving past Haldon Gate (742 ft.), and near Buller's Hill (827 ft.), to near the race course, the members alighted for lunch

at a gravel pit (766 ft. above sea-level). Here Mr. Woodward made some general remarks on the gravels which cap the Greensand, and which occur over a considerable area in the Teign Valley, near Newton Abbot. When engaged in the re-survey of that area in 1874 he was puzzled to account for the coarse gravels which occupied the Bovey Basin, and seemed to be connected with the plateau gravels of Little and Great Haldon, portions of which were then mapped by his colleague, Mr. Clement Reid. The age of these doubtful superficial deposits, which he had been disposed to regard as Drift,* had now been settled by Mr. Reid, who, working steadily westward from the Isle of Wight and Bournemouth, had noticed the incoming of various rocks in addition to the customary flint-pebbles, and, moreover their increasingly angular character.† The well-known gravel at Blackdown Hill, near Portisham, was a noteworthy instance. Mr. Reid now connected the coarse gravels on Haldon and near Newton Abbot with the Bovey Beds, and he had called attention to seams of white clay and rough quartz sand on Haldon. The Bovey Beds, which comprise gravels and sands, white clays and lignites, were regarded by Mr. J. Starkie Gardner as of the same age as the Pipe-clays of Poole—Lower Bagshot.‡ The white clays and quartz sands in both regions were presumably derived from the decay of granite in the regions, of which Dartmoor was a remnant, and it would be an interesting task for Devonshire geologists to help in tracing out the course of the old river which flowed in Eocene times from Bovey Tracey and Haldon to what is now Poole—across a tract of uplands which, however, has been considerably displaced here and there by post-Eocene earth-movements. The greywethers on Salcombe Hill, near Sidmouth, with their angular contents, served in a striking way to support the views of Mr. Reid.

Attention was now directed to the Upper Greensand, and it was remarked that the upper beds had yielded many Corals, such as *Placosmilia*, *Thamnastræa*, and *Trochoseris*, which had been recorded and described by Prof. M. Duncan.§ Lower down there were cherty beds, in which an example of *Pecten elongatus ?* was obtained, while *Holaster fossarius* from Haldon was exhibited by Mr. Woodward. Beneath these beds were greenish-grey sands with indurated bands and fine conglomeratic layers,|| the whole resting on the New Red breccia.

Mr. Collins conducted the party to a gully north of the race course and west of Woodlands Covert, where the junction of the chert-beds and sands was seen. In the harder beds of sand and

* *Quart. Journ. Geol. Soc.*, vol. xxxii, p. 230; *Proc. Geol. Assoc.*, vol. xi, p. xlviii.
† *Quart. Journ. Geol. Soc.*, vol. lii, p. 490, and liv, p. 234.
‡ *Proc. Geol. Assoc.*, vol. vi, p. 100.
§ *Quart. Journ. Geol. Soc.*, vol. xxxv, p. 89.
|| Apparently a similar bed had been noted at Salcombe, near Sidmouth, by Godwin-Austen, *Trans. Geol. Soc.*, ser. 2, vol. vi, p. 449.

glauconitic sandstone numerous fossils belonging to the Blackdown Beds were found, including *Arca*, *Cytherea plana*, Sow., *Trigonia dædalea*, Park., and *T. scabricola*, Lyc. Specimens of *Cucullæa* and *Protocardium hillanum*, Sow., were exhibited by Mr. Collins.

The members were then driven by Kennford and Alphington to Exeter, where, after dining at the Rougemont Hotel, most of the members departed for their homes.

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CYCLING EXCURSION FROM WINCHFIELD TO WOKINGHAM.

SATURDAY, APRIL 8TH, 1899.

Director: H. W. MONCKTON, F.L.S., F.G.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by* THE DIRECTOR.)

LEAVING Winchfield a little before half past three, the party cycled to the brick-field on the south-western side of Hazeley Heath, 2¼ miles from the station.

The rather sandy clay worked belongs to the Middle Bagshot Series; the heath, in fact, is a Middle Bagshot outlier, and it is capped by a gravel, the top being a flat expanse, with a level of a little over 288 ft. above Ordnance Datum. The details are clearly shown on Sheet 284 of the New Series Geological Survey Map recently published.

There are numerous gravel-pits, one of which was selected for examination. The gravel was seen to be fairly well stratified with thin beds of sand here and there, the sandy parts frequently showing current bedding. In some places the stratification was less well marked, and often there was a certain amount of contortion and patches of mottled gravel, but these seemed to be always near the surface of the ground. In one section, 7 ft. deep, the contorted part extended 5 ft. from the surface, whilst close by a 10 ft. section showed no contortion. The gravel consists mainly of sub-angular flints, whose brown colour suggests long exposure to atmospheric agencies, and possibly they have been derived from older drift. There is a good deal of cherty material from the Hythe Beds of the Lower Greensand, whose nearest outcrop is now fifteen miles to the south-east. The locality is on the western margin of the area over which this Hythe Bed material has been distributed.* The Director gave reasons for believing that this and all the gravels about were old

* See H. W. Monckton, *Quart. Journ. Geol. Soc.*, vol. xlviii, map on p. 38.

river gravels,* and no one present seemed inclined to dispute the point.

Leaving Hazeley Heath the members crossed the little river Hart and ascended Star Hill on to Hartford Bridge Flats, about 310 ft. O.D. A halt was made at a gravel-working near Cooper's Farm, $5\frac{1}{2}$ miles from the start. In composition the gravel is very similar to that of Hazeley Heath, and the Director thought there must be a slip of the pen in Mr. Salter's statement (*Proc. Geol. Assoc.*, vol. xv, p. 272) that "the bulk of the material composing the gravels in this district is derived from Tertiary strata, and but little from the Wealden." The Director thought the sub-angular flints of which the gravel mainly consists were derived from the Chalk, or from older drifts, and he doubted whether any of the material came from Wealden Beds.† There are, no doubt, a fair number of flint pebbles from Bagshot Pebble Beds. A section, 7 ft. deep, showed mottled gravel with scarcely a sign of stratification, and there is a somewhat unusual absence of stratification in the gravel all over the top of these flats, and as their level is over 300 ft. O.D., they furnish a good example of high-level gravel with but little stratification.

The party then crossed the valley of the Blackwater into Berkshire. and the next halt was at Finchampstead, in Sheet 268 of the Geological Survey Map, New Series.

The green-coloured sands of the Middle Bagshot were seen below East Court, and at the top of the hill a road-section at North Court showed yellow Upper Bagshot sand. Scarcely a sign of bedding is seen in that series, and here and there small patches of green sand were observed. Finchampstead Ridges are capped by gravel at a level of about 330 ft. O.D. The party cycled, by way of Warren Lodge and the Nine-mile Ride, to some brick-fields between Wellington College and Wokingham, having ridden 12 miles from Winchfield Station.

Up to the present the route had lain over country, which, it is believed, had not previously been visited by the Association, but the brick-fields in the Nine-mile Ride received attention on June 21st, 1890.‡

The first pit visited showed a good exposure of the current-bedded Lower Bagshot sand and above it was a laminated clay which is worked for brick-making. This, the Director thought, belonged also to the Lower Bagshot, but Dr. Irving and others hold that it is Middle Bagshot, and in any case it is very near the

* See *Proc. Geol. Assoc.*, vol. xiv, p. 127.

† By the courtesy of Mr. Monckton, I am permitted to say that in the remarks quoted above, I refer to the Wealden *district* (not *beds*), and that I regard some of the earlier drifts of this district as probably of Pliocene age. Hence the sentence would read thus: "The bulk of the material (*i.e.*, the rounded flint pebbles and perhaps the brown sub-angular flints) composing the gravels in the district is derived from Tertiary strata (*i.e.*, Bagshot or perhaps Pliocene Drifts), and but little (such as small quartz pebbles and chert) from the Wealden" *district*.—A. E. SALTER.

‡ *Proc. Geol. Assoc.*, vol. xi, p. clvi.

line of division between the two series. The surface of the ground is formed of gravel of variable thickness with a level of about 240 ft. O.D., and both the gravel and underlying clay are much contorted. An excellent example of these contorted beds is shown in a photo by the Rev. H. P. Kempthorne, part of which was reproduced in the report of a former excursion,* which was under the direction of Dr. Irving.

On the motion of the President, a cordial vote of thanks to the Director was passed, and the members cycled to Wokingham Station, where they arrived at about 6.30 p.m., the total distance covered having been 15 miles.

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EXCURSION TO NEW RAILWAY, WALTON-ON-THE-HILL, AND BETCHWORTH.

SATURDAY, APRIL 15TH, 1899.

Directors: W. WHITAKER, F.R.S., Pres. G.S., and W. P. D. STEBBING, F.G.S.

Excursion Secretary: BEDFORD MCNEILL, F.G.S.

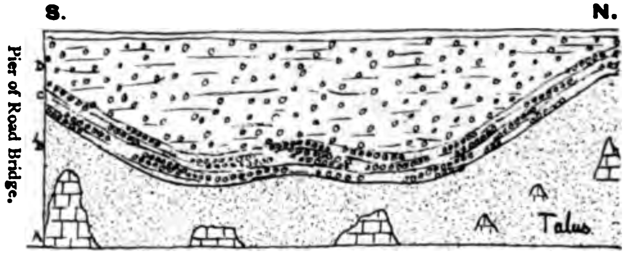
(Report by MR. STEBBING.)

THE members reached Kingswood at 2.2 p.m., and walked to the cutting on the western side of the tunnel under Walton Heath, in progress for the Chipstead Valley line. At its south-eastern end the cutting showed Chalk covered with pipes of Thanet Sand, and redeposited Woolwich Clay with flint pebbles; near the working face at the north-western end the Thanet Sand seemed to occur in mass. A point of interest, however, in this cutting was the way in which the Chalk had

* *Proc. Geol. Assoc*, vol. xi, p. clxi.

been worn to a series of pinnacles, divided by holes or pipes penetrating almost down to the level of the railway; in some cases the pinnacles rise to within 4 or 5 ft. of the surface.

Thence the party walked to the present working face south of the Walton Road Bridge and to the site of the Walton Station, passing what remained of the section figured below. Returning on the western side of the cutting the party saw a fairly good section of Thanet Sand with an undulating surface, and two or three pinnacles of Chalk standing up in it. On the south side of the Walton Road Bridge, but on the opposite side of the cutting, the strata in the cutting were the same as those previously seen on the north side of the bridge, but the movement that had taken place



W.P.D.S.

SECTION IN RAILWAY CUTTING, WALTON-ON-THE-HILL.
FEBRUARY, 1899.

Length of Section, about 35 yards. Height of Section, about 40 feet.

A. Chalk. B. Thanet Sand. C. Buff Sand with pebbles (stratified). D. Mottled Clay with pebbles.

owing to the destruction of the Chalk was more pronounced on account of its occupying less space longitudinally. The Directors pointed out that, though the Thanet Sand was marked in the Drift Edition of the Geological Survey Map as covering a large patch of the surface of the ground about here, at no spot in these cuttings did it reach the surface, except in the case of some pipes at the northern end.

After tea at Walton Mill the party proceeded to a small sand-pit on Headley Heath, containing sand and a gravel largely composed of flint pebbles. The gravel occurs in isolated patches on high ground from Netley Heath eastwards, and is of uncertain age. Walking southward, the party reached the edge of the North Downs, near Betchworth Clump. Thence they descended to the Chalk-pits, which we believe had not previously been visited by the Association. Here was seen a section embracing a large part of the Middle and Lower

Chalk. The Directors pointed out in descending order (1) the zone of *Echinoconus subrotundus*, equivalent to the zone of *Terebratulina gracilis*, which does not seem to occur here; (2) the zone of *Rhynchonella cuvieri*, called by the quarrymen "Burr Chalk," and equivalent to the Melbourn Rock; (3) the zone of *Belemnitella plena*, a very distinct narrow band round the quarry, and forming the top of the Lower Chalk; and (4) the zone of *Holaster subglobosus*. The distinction between zones 1 and 2 was very easily seen on one side of the pit. The marked difference in character between the massive, thickly-bedded Middle Chalk, and the more thinly-bedded and marly Lower Chalk was well seen.

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1872. ————.—"The Geology of the London Basin." *Mem. Geol. Survey*, vol. iv.
1884. DALTON, W. H.—"Excursion to Epsom and Dorking." "Record of Excursions," p. 86.
1895. MONCKTON, H. W., and STEBBING, W. P. D.—"Excursion to Betchworth and Headley." *Proc. Geol. Assoc.*, vol. xiv, p. 124.
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EXCURSION TO THE THAME DISTRICT.

SATURDAY, MAY 6TH, 1899.

Director: A. M. DAVIES, B.Sc., F.G.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by* THE DIRECTOR.)

A SMALL party assembled at Thame Station shortly before noon, and at once drove along the Towersey road into the adjoining county of Bucks., where the first turning to the left soon brought them to a small quarry (p. 39 *). Here the Director, after briefly calling attention to the Chiltern escarpment with the conspicuous Whiteleaf Cross showing the Chalk, and the Gault plain at the base, remarked that the small stone-pits in the Portland of this district were worked mainly in the winter, and that consequently none of those they would see that day would show exactly the sections described in his paper. In this case the two lowest beds were now hidden, and the nodular chert at the top was but indifferently exposed. The blocks of Portland limestone

* This and subsequent references are to the Director's paper in this volume of PROCEEDINGS, *ante*.

stacked near the entrance were full of the characteristic fossils—*Trigonia gibbosa*, *Cardium dissimile*, *Pecten lamellosus*—and the members soon collected a number of *Paludinæ*, almost all under-sized, from the Purbeck marl, Bed 7.

The party then drove to the pit near King's Cross (pp. 40, 41). Here the creamy limestones were found exposed to a depth of 7 ft., and, among other fossils, Mr. Young had the good fortune to obtain a *Perisphinctes* (*Amm.*) *boloniensis* of portable size. The greater share of attention in this pit, however, was claimed by the uppermost clayey and marly beds, regarded by the Director as probably Middle or Upper Purbeck. This view was subjected to a severe fire or criticism, and counter propositions that the clay was Wealden, Gault, Boulder-Clay, or an artificial deposit in an old cutting, were quickly raised. After much discussion, the general conclusion arrived at was that part of the topmost marly portion might perhaps be artificial, that the rest was of freshwater origin, newer than the Purbecks of the district, and certainly not Gault nor Boulder-Clay. These conclusions were not inconsistent with those of the Director.* It should be mentioned that fragments of carbonaceous material were found in the black clay, and several unmistakable *Unios* in the sandy bed (No. 5), but these were too fragile for preservation.

The party then walked down the hill to the Dad Brook, along the line of section (Fig. 2, p. 23, and Map, p. 54). The outcrops of limestone and sand were seen by the roadside, and lydite-pebbles were found at the junction of the sands with the underlying clay. Among these pebbles Mr. Leighton found a phosphatised fragment of an Ammonite—a find of interest (*cf.* p. 25). At Cuddington creamy limestones were seen to crop out in the roadside.

The party drove next to Long Crendon. On the way the Director pointed out the line of the proposed new railway from Prince's Risboro' to Grendon Underwood, which may yield some valuable exposures near Haddenham. The first section examined at Long Crendon was that by the southern windmill (p. 22), visited previously by the Association in 1893. The present visit was opportune, as the owner has decided not to work it any more. Already the creamy limestones for which it was worked are hidden, and the pale grey clay (Bed 3, p. 22) could only just be seen at one point. The rest of the section was still in such good condition as to cause general regret that no photographer was at hand. Mr. Parker, however, produced some photographs of the section taken a few years ago.

* I am glad to take this opportunity of making a correction, the need for which was pointed out to me at this point, in the section given on p. 40. Beds 7, 8, and 9 are properly one bed, the transition from one to the other being quite gradual. They were marked as such in my field note-book.—A.M.D.

Mr. Leighton drew attention to Bed 8 of the section (p. 22) as closely corresponding to the basement-bed of the Gault at Folkestone and elsewhere; a hunt was made in it for fossils, and a shark's tooth was found by Miss Foley.

The sections on the steep descent of the road to Thame were next examined (p. 21). After the lower beds of the limestone sequence had been examined the outcrop of the same beds in the roadway was observed, and some of the members maintained that the dip shown by these beds would carry them below the sands seen in the next exposure down the hill. The Director said that this was not the case, as he had assured himself at more than one point that the sands passed beneath the limestones. He dismissed the suggestion that the sands were Lower Greensand by the assertion that they were "too green," the *absence* of glauconite being in this district a characteristic of the "Lower Greensand." He maintained that the lydite-bed here seen with 10 ft. of sand visible below was on the same horizon as the lydite-bed which they had seen immediately above the Hartwell Clay at Dadbrook Hill. A hasty visit to the brick-field at the foot of the hill tended to confirm this view in so far as the clay there was seen not to resemble Hartwell Clay, at any rate lithologically, being rather shaley, and not sandy at all. The same was the case at Thame, the Director said, where he had that morning seen the base of the sand exposed in a drainage cutting, and had been told by the engineer that the clay beneath the sand was very stiff.

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Geological Survey Index Map, Sheets 11 and 12. Price 2s. 6d. each.

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EXCURSION TO ILFORD.

May 13th, 1899.

Director: T. V. Holmes, F.G.S.

Excursion Secretary: W. P. D. Stebbing, F.G.S.

(*Report by* The Director.)

The members left Liverpool Street Station at 2 p.m., arriving at Ilford at 2.15. They then walked to the Cauliflower Brickfield, the property of Mr. R. Page, who had kindly given permission for its inspection. The side of this pit showed 12 to 14 ft. of brick-earth above sand.

The Director remarked that the old river deposits of the Thames and its tributaries, on which they were standing, covered a broad belt of flat country lying between the alluvial flats bordering the Thames (which constituted the most recent river deposits) and the higher ground of London Clay north of Wanstead, Romford, and Upminster. The level of this tract varied from more than 100 ft. above the sea, towards its northern limits, to 15 or 16 ft. close to the marshes of the Thames between Barking and Rainham. Between London and Gravesend, as between Windsor and London, the Thames had not only been cutting its valley deeper and deeper, but had also been occupied in taking a more southerly course than it once followed. This was shown by the much greater breadth of river deposits to the north than to the south of the present stream. It should also be remembered that the fall of the river would make a deposit 60 or 70 ft. above Ordnance Datum west of London, for example, the equivalent of a bed at a considerably lower level east of that city. Around the Ilford brick-pits the surface level is from 40 to 50 ft. But Thames Valley Gravel had been seen at a height of about 100 ft. above O.D.,* on the new railway between Upminster and Romford, overlying the Chalky Boulder-Clay, the latest deposit o the Glacial Period in that part of England. The Ilford deposits must therefore be still more decidedly "post-Glacial" in the only sense in which the term can be used, that is in the sense of being more recent than the Chalky Boulder-Clay.

These old river-deposits consist of sand and gravel occasionally capped, as at Ilford, by a considerable thickness of loam or brick-earth. The gravel and sand has, doubtless, been brought down in the channel of the stream, while the brick-earth is inundation-mud, deposited above the sand and gravel during floods. Mammals would be especially liable to be drowned

* *Quart. Journ. Geol. Soc.*, vol. xlviii (1892), p. 365, and vol. l (1894), p. 443.

during floods, while at the same time their remains, when quietly buried in the comparatively impermeable mud, would have a much better chance of preservation than if brought down in the channel of the stream.

The Director concluded his remarks by referring to the most important and interesting of the mammalian remains which had been found at Ilford. In answer to a question as to the origin of the curious steep-sided hollows, filled largely with other material, often seen near the surface of the brick-earth, the Director replied that they had probably originated in natural cracks, the result of drying and shrinking, which in many cases had been begun when the brick-earth was being deposited. These had been enlarged by the action of the weather, and ultimately filled up with material at various periods and from a variety of sources.

Recrossing the railway, the party proceeded along the Romford road in a north-easterly direction. Passing the new Seven Kings Railway Station, they entered, by permission of the G. E. R. Company, the large ballast-pit on the northern side of the Romford road, about midway between Seven Kings and Chadwell Heath Stations. There they found 12 to 14 ft. of gravel capped by 3 or 4 ft. of brick-earth. The section was very fresh and clear, and the gravel was seen to be very well stratified and uniform in composition.

A vote of thanks having been accorded to the Director, on the motion of Mr. E. T. Newton, the party glanced at the old G. E. R. ballast-pit, south of the road, and made their way to Seven Kings or Romford Railway Stations.

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1871. Dr. H. WOODWARD.—"Record of Excursions," p. 173, and *Proc. Geol. Assoc.*, vol. ii, p. 273.

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1893. F. C. J. SPURRELL.—"Excursion to Ilford." *Proc. Geol. Assoc.*, vol. xiii, p. 53.

EXCURSION TO REIGATE.

SATURDAY, JUNE 3RD, 1899.

Directors: MISS M. C. CROSFIELD and the REV. R. ASHINGTON BULLEN, B.A., F.L.S., F.G.S.

Excursion Secretary: A. C. YOUNG, F.C.S.

(*Report by* MISS CROSFIELD).

THE party met at Reigate Station about 2.30, and first visited a sand-pit in the Croydon Road where the junction of the Gault and Lower Greensand is well seen. Phosphatic nodules and fragments of wood were found, but no fossils. Crossing the Gault on Wray Common, the company walked westward by Raglan Road at the foot of the Upper Greensand escarpment, and thence to a pit in Upper Greensand just below Colley Hill, where the following section is exposed: At the top, Chloritic Marl, 7 ft. 6 in.; Cherty band, 6 in.; Hearthstone, 6 ft.; Cherty band, 6 in.; Hearthstone, 5 to 6 ft.; Fire- and building-stone, 6 ft. Sponge spicules occur abundantly in the cherty bands. Two small faults were distinctly visible. In the "Horseshoe" quarry (450 ft. O.D.) adjoining, Mr. George Taylor, on whose property the Association was now assembled, met the party. He stated that the tunnels recently discovered in the hill were 200 years old. From borings made for water, he found that the thickness of the Upper Greensand here was about 55 ft. After a vote of thanks had been passed to Mr. Taylor, the Rev. R. Ashington Bullen described the Holocene deposit in the same quarry. It is 4 ft. thick, and yielded *Bulimus montanus*, *Helicigona arbustorum*, and *Clausilia rolphii*, no longer extant there. *Terebratulina gracilis* from the Middle Chalk, and an abnormal facetted nodule (Hydrated MnO), probably from the Upper Greensand, occurred. The abundance of *Arion ater* (granules) and *Carychium minimum* at 2 to 3 ft. levels attest moister conditions than now obtain.* A Neolithic scraper occurred at a depth of $2\frac{1}{2}$ ft. A few of the members scaled Colley Hill to see a block of ferruginous conglomerate, measuring 46 in. × 40 in. × 24 in. Mr. H. W. Monckton considers this mass of cemented angular and rounded pebbles to be a relic of a deposit of sand, etc., similar to that which has been mapped at Chipstead $2\frac{1}{2}$ miles N.E., and to a larger patch at Headley Heath $2\frac{1}{2}$ miles N.W. from the site of the block under discussion. Unfortunately, this conclusion does not carry us very far, for the deposit is mapped and described as "Sands of Doubtful Age."† A visit was then paid to the Reigate Hill pit in Lower and Middle Chalk.

* *Proc. Malacological Soc.*, vol. iii.

† Whitaker, "Geology of the London Basin." *Mem. Geological Survey*, vol. iv, p. 336 (1872).

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Geological Survey Map (1 in. Scale), Sheet 8, Drift. (8s. 6d.)
Geological Survey Index Map, Sheet 12. (2s. 6d.)
Ordnance Survey Map (New Edition), Sheet 286. (1s.)

1887. TOPLEY, W.—"Excursion to Redhill and Reigate." *Proc. Geol. Assoc.*, vol. x, p. 154.
1889. WHITAKER, W.—"Geology of London." *Mem. Geol. Survey.*

EXCURSION TO STAINES.

SATURDAY, APRIL 22ND, 1899.

Director: W. WHITAKER, F.R.S., PRES. G.S.

Excursion Secretary: BEDFORD MCNEILL, A.R.S.M.

(*Report by* H. A. ALLEN.)

A LARGE party arrived at Staines at 2.36 p.m., and at once proceeded to the offices of the Water Companies, where a large series of mammalian remains had been arranged for inspection. The specimens were obtained from the Alluvium during the progress of the works. The geologists next walked to the aqueduct, excavated in Alluvium and River Gravel. Thence they were conducted, by train kindly placed at their disposal by Messrs. John Aird and Co., to the reservoirs in process of construction. The Director explained the geology of the district, and stated that the reservoirs are cut through river gravel to London clay, the junction being fairly even.

In the absence of Mr. R. E. Middleton, M.I.C.E., the guidance of the members was kindly undertaken by Mr. M. B. Duff, the resident engineer. The method of making a puddle-trench (of London clay) through a mass of gravel resting on clay, so as to render it capable of containing a body of water 412 acres in area, was clearly explained. The average depth of water will be 31 ft., maximum depth 39 ft. Attention was next directed to the fine sections of London clay and gravel exposed.

Many large blocks of greywether sandstone, which had been found in the gravel, were seen. One mass was observed in the bank by the Director; the bottom part of it was soft and could be readily disintegrated into sand.

ORDINARY MEETING.

FRIDAY, MARCH 3RD, 1899.

J. J. H. TEALL, M.A., President, in the Chair.

The following were elected members of the Association: William J. Stokes and F. L. Kitchin, M.A., Ph.D.

In the unavoidable absence of Dr. Abbott, through illness, a lecture was delivered by Mr. G. W. LAMPLUGH on the "Geology of the Isle of Man," dealing more particularly with the glacial

phenomena. The lecturer gave a lucid account of his observations in the island, and illustrated his remarks by some excellent lantern slides taken by Prof. Watts.

ORDINARY MEETING.

FRIDAY, APRIL 7TH, 1899.

J. J. H. TEALL, M.A., President, in the Chair.

The following were elected members of the Association: W. Edwards, F.G.S., and Howard Fox, F.G.S.

The PRESIDENT then read a paper by Dr. Charles Barrois on "The Geology of Brittany," with special reference to the Whitsuntide Excursion.

ORDINARY MEETING.

FRIDAY, MAY 5TH, 1899.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

The following were elected members of the Association: Arthur S. Horne, N. Alexander Mackie, Arthur W. Clayden, M.A., F.G.S., A. R. Hunt, William E. Hughes, B.A., F.G.S., J. Allen Howe, William Arthur Savage, M.R.C.S., L.R.C.P., etc., J. A. Rimmington, Miss A. T. Barnard, Miss K. A. Burke, E. B. B. Newton.

Mr. H. J. OSBORNE WHITE read a paper, by Prof. W. M. Davis, of Harvard University, entitled "The Drainage of Cuestas," the paper being illustrated by diagrams.

ORDINARY MEETING.

FRIDAY, JUNE 2ND, 1899.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

The following were elected members of the Association: H. Bauerman, F.G.S., J. W. Jarvis, the Right Hon. Sir John Lubbock, Bart., M.P., F. Nichols, Alfred B. Trestrail.

The following papers were read:

"The Pleistocene Deposits of the Ilford and Wanstead District," by MARTIN A. C. HINTON.

"The Pleistocene Mollusca of Ilford," by A. S. KENNARD and B. B. WOODWARD, F.L.S., F.G.S.

"The Raised Beach and Rubble Drift at Aldrington, between Hove and Portslade-by-Sea, Sussex, with Notes on the Microzoa," by FREDERICK CHAPMAN, A.L.S., F.R.M.S.

Mr. G. E. DIBLEY exhibited a specimen of *Goniaster*, embedded in flint, from the Middle Chalk of Cuxton.

A SKETCH OF THE GEOLOGY OF THE LOWER CARBONIFEROUS ROCKS OF DERBYSHIRE.

WITH SPECIAL REFERENCE TO THE LONG EXCURSION OF 1899.

By H. H. ARNOLD BEMROSE, M.A., F.G.S.

PLATES III—VII.

(*Read July 7th, 1899.*)

CONTENTS.

INTRODUCTION.

THE district described in this sketch includes the north and north-west portions of Derbyshire, and roughly coincides with the whole of the High Peak Division and the northern half of the Western Division of the county. It consists of the hill country of Derbyshire, which forms the southern spur of the Pennine Chain. The town of Glossop is on the north-west; Buxton and Chapel-en-le-Frith are on the west; Castleton, Hope and Hathersage near the centre, Matlock, Crich, and Ambergate are on the east, and Ashbourne, Kniveton, and Wirksworth on the south. It lies east of the watershed of the central part of England, and is drained by the Derwent and the Dove, which flow into the Trent.

The *Derwent* rises in the moorlands in the northern part of

the county, and for some distance forms the boundary between Yorkshire and Derbyshire. It flows in a south-easterly direction, and after passing through Hathersage, Rowsley, Matlock, Ambergate, and Derby, flows into the Trent beyond Draycott. The *Alport* and *Ashop* rise on Alport Moor, and in the course of a few miles unite at Alport Bridge, and finally enter the Derwent at Ashopton. The *Noe* rises on the flanks of Kinder Scout, in Edale, flows through the valley of that name, and joins the Derwent, at Mytham Bridge. The *Wye* rises on the northern flank of Axe Edge, near Buxton, flows through Buxton, Miller's Dale, Monsal Dale, and Bakewell, and joins the Derwent at Rowsley. The *Amber* rises a few miles north-west of Ashover, and enters the *Derwent* at Ambergate. The *Dove*, which for some distance forms the boundary between Staffordshire and Derbyshire, rises on Axe Edge, flows through Hartington, Dove Dale, and Ashbourne, into the Trent near Burton.

A well-marked anticline passes through the district in a north-west direction. The beds dip steeply to the west, under the Coal Measures of Lancashire and North Staffordshire, and with a more gentle dip to the east, under those of Yorkshire and Derbyshire. In the north of the county a large dome-shaped mass of Mountain Limestone has been brought up. The severed strata on the west and east sides of the anticline, which were once continuous across the arch, have been removed by denudation which has not only laid bare the Mountain Limestone, but removed a small thickness of the upper beds. If we were to start on the Mountain Limestone and travel a short distance in an easterly or westerly direction, we should pass the various members of the Carboniferous series of rocks in succession up to the Coal Measures.

A smaller anticline runs through Ashover, parallel to that of the Pennine Chain. At Matlock the limestone dips to the east beneath the Yoredales and Millstone Grit series, which form a small basin and soon dip west. This dip and the fall of the ground in the valley of the Amber expose the beds down to the Mountain Limestone at Ashover. Fig. 1 gives a rough section across the county from Buxton on the N.W. to Stretton on the S.E.

The Mountain Limestone from Doveholes through Castleton and Bradwell to Eyam is bounded by a narrow belt of lower ground consisting of Yoredale shales. Slopes which run nearly parallel to the limestone boundary rise from this depression. These slopes are the edges of several outliers of Shale Grit which once formed a large plateau extending from Chapel-en-le-Frith to Eyam, and including the moors in the extreme north of the county. Edale, and the valley of the Derwent near Hope, Bamford and Hathersage, have divided this plateau into several outliers.

Near the centre of the Shale Grit-plateau is an outlier of Kinder Scout grit, which is called the Peak. Though it is a flat table-land it reaches a height greater than any other part of Derbyshire, some portions of it being 2,000 ft. above the sea. The highest point in the limestone area reaches a height of only 1,800 ft. The Shale Grit dips under the Kinder Scout grit, which on the west forms a ridge from Chapel-en-le-Frith through Hayfield to Glossop, and on the north extends some distance east from Glossop into Yorkshire. On the west this grit forms the escarpments of Derwent and Bamford Edges. The various members of the Millstone Grit groups may be traced as far south as Belper. The Chatsworth or Rivelin grit forms the fine escarpments of Froggat, Curbar, and Baslow Edges, east of Stoney Middleton. The southern part of the limestone area is bounded by the Yoredale shales, which in turn are covered unconformably by the Triassic rocks of the Midlands. On the west as far as Doveholes the limestone is bounded by the Yoredale rocks, though the boundary is often faulted. Near Hartington is an outlier of Millstone Grit on Sheen Hill in Staffordshire. About Earl Sterndale the boundary is much complicated by faults, and west of Buxton the limestone is faulted against the Yoredales and Shale Grit which dip under the Millstone Grit of Axe Edge and the Goyt Basin. Between Buxton and Doveholes the limestone is

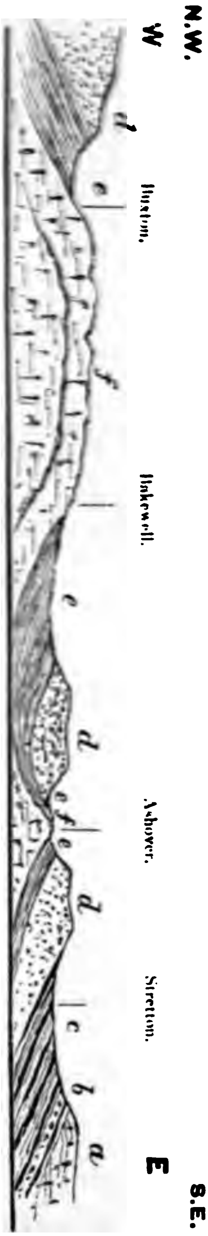

FIG. 1.—SKETCH-SECTION ACROSS DERBYSHIRE.

a Permian Limestone
b Permian Sandstone
c Coal Measures
d Millstone Grit
e Yoredale Rocks
f Mountain Limestone

bounded by the Yoredale rocks, which dip under the Millstone Grit of Combs Moss on the west.

The district is noted for its fine scenery. The Mountain Limestone, with its outlines generally smooth, its well rounded grassy slopes, and deep, narrow dales and ravines, presents a marked contrast to the wild moorlands and escarpments of the Millstone Grit. These narrow dales or gorges have sometimes a stream at the bottom, whilst at others the valley is quite dry, the water having found its way underground. Some of the dales probably have been formed by the falling in of the roof of an old underground watercourse, but others—especially that of the Derwent, at Matlock—are to be explained in a different manner. The river, after flowing in the broad valley of shale from Darley Dale, suddenly enters the Mountain Limestone which rises across its path, instead of continuing in the shales and skirting the limestone as far as Cromford. The course of the river evidently was determined before the valley of Darley Dale was formed, and the cutting of the gorge in the limestone and the broad valley in the shale proceeded together.

The Wye and the Dove also illustrate the influence of different rocks in the erosion of river-valleys. The Wye, in its course from Buxton to Monsal Dale, flows through a deep valley in beds of massive Mountain Limestone. At Chee Tor and at Cressbrook the stream has cut a narrow gorge, bounded by almost perpendicular cliffs. These steep slopes are often covered by ivy and shrubs, which contrast strongly with the bareness of the limestone. When the river reaches the thin upper beds of limestone, the valley becomes wider, and in the broad shale-valley near Haddon Hall, the Wye pursues a serpentine course.

The Dove, after flowing in the shales near Hartington, enters the limestone near Beresford Hall, and its course for several miles consists of the narrow valley or gorge known as Dovedale. It then enters the shales again near Thorpe, and the valley becomes wider and less rugged.

In the gritstone country some valleys run parallel to the strike. They often lie between two escarpments of grit which are separated by a bed of shale. A good instance is given by Messrs. Hull and Green in the valley of Ashop Clough. The south side of the valley is formed by an escarpment of grit resting on a thick bed of shale. The north side is formed of a dip slope of a sandstone bed which crops out from under the shale. The river runs along the top of the lower sandstone with a steep cliff of shale on the south which it is undermining and wearing back.

A third class of valley is caused by streams flowing down the escarpment of one of the parallel valleys, and cutting back into the hill until at length a transverse valley is formed.

The chief points of geological interest in the Mountain

Limestone, besides its fossil contents, are undoubtedly the igneous rocks, the lead mines, the caverns and underground watercourses. From a very early date lead, zinc, and other minerals have been obtained from the limestone. The rock is also largely quarried for making lime, road metal, and for building purposes. It also provides sand and clay for fire bricks, and chert, which is used largely in the Potteries.

THE LOCAL ROCK FORMATIONS.

The following rocks occur in the district covered by this sketch.

RECENT.—Alluvium. Peat Bogs. Calcareous tufa, stalactitic formations.
PLEISTOCENE.—Cavern deposits, Glacial drift, boulders, sands, and clays.
PALÆOZOIC.

Upper Carboniferous, Millstone Grit		1. Rough Rock. Shale. 2. Sandstones and Shales. Shale. 3. Chatsworth Grit. Shale. 4. Kinder Scout Grit. Shale. 5. Shale Grit.
Lower Carboniferous.	Yoredale	1. Shales with thin Sandstones. 2. Shales with thin beds and nodules of earthy Limestones.
	Mountain or Carboniferous Limestone	Limestone with thin Shales and clay partings.
	Igneous Rocks (Toadstone)	Contemporaneous with the Yoredale Limestones and Mountain Limestone and also intrusive.

The above divisions of the Carboniferous series are those adopted by the Geological Survey.

The Shale Grit was formerly placed amongst the Yoredale rocks under the name of Yoredale Grit, and as such it appears on the 1-inch geeological maps of Derbyshire which were made about fifty years ago, and revised up to about the year 1867. Since then it has been transferred to the Millstone Grit, and forms the lowest member of that series. Some further remarks about these divisions will be found under the head of Yoredale Rocks.

The Mountain Limestone.

The Mountain Limestone, of which all but a small portion on the S.W. is in the county of Derbyshire, forms an irregularly shaped inlier, measuring about twenty miles from north to south, and ten miles from west to east. In addition to this there are three small inliers, viz., at Ashover and Crich on the east, and at

Kniveton on the south-west. The large inlier is a pericline or dome, the longer axis ranging N.N.W. The beds dip away from the centre of the mass in every direction, and, generally speaking, the dip at the edges is at right angles to the boundary, which, according to the geological maps, is partly natural and partly faulted. The dip on the west is generally greater than that on the east.

A closer examination of the limestone area shows that this conception of a simple pericline must be modified, and that it is made up of a number of smaller domes and basins.

The three promontories in the limestone on the east, and on which Stoney Middleton, Bakewell, and Matlock Bath are situated, are portions of minor domes, whilst the bay in the limestone near Ashford, which is occupied by the Yoredale rocks and the still larger one containing the Stanton outlier of Kinder Scout grit, represent basins in the limestone. So that a section drawn nearly north and south from Eyam to Carsington would show at least three anticlines and two synclines. A parallel section on the west would show at least two anticlines and one syncline.

A detailed acquaintance with the district shows that though sometimes the beds (especially those near the centre of the area) are horizontal, at others they have been thrown into numerous folds.

The limestone is the lowest rock in Derbyshire. Its thickness is unknown, the basement beds not having been reached. Owing to the expense of working at great depths, and the difficulty of keeping out the water, coupled with the fact that the upper beds have been found to be richest in ore, mining shafts have been sunk to no great depth. In estimating the thickness reached, we therefore have to rely on the sections seen in the valleys. The section made by the officers of the Geological Survey along the Midland Railway, between Monsal Dale and Buxton, shows a thickness of nearly 1,600 ft. for the limestone and igneous rocks or toadstone associated with it.

Section of the Mountain Limestone between Monsal Dale and Buxton :

		ft.
1.	Thinly bedded limestone, somewhat earthy, with layers and nodules of chert, and thin shale partings in the lower beds	250
2.	Thickly bedded limestone	50
3.	Thinly bedded limestone with chert	90
4.	Toadstone, perhaps in places as much as	100
5.	Massive white limestone. Miller's Dale rock, with perhaps a bed of Toadstone in the middle, at least	320
6.	Toadstone, about	20
7.	Very thickly bedded white limestone, Chee Tor Rock ...	500
8.	Limestones, more or less concretionary, with shale partings	150
9.	Limestones, some thickly and some thinly bedded ; of these there is seen about	100
	Total thickness shown without reaching the bottom ...	1,580

The following approximate estimate was made by the author, based on the observed dips of the rocks, and taking into account the rise and fall of the ground. A continuous section was not seen, and it is probable, from indications of a slight roll of the beds north of Grange Mill, that the estimate is somewhat in excess of the truth.

SECTION FROM WINSTER TO GRANGE MILL, N. TO S.

	ft.
Limestone, cherty in the upper part	641
Toadstone (lava)	147
Limestone	911
Toadstone (Bedded Ash)	93
Limestone	508
Toadstone (agglomerate of Grange Vent)	—
Total	2,300

A short distance south, the anticline is passed; so that these are the lowest beds reached in this part.

With the evidence at present at our disposal, we may conclude that a greater depth than 2,000 ft. has not been reached, and that the lowest beds seen are probably those at Grange Mill or in the Valley of the Wye, near Pig Tor Tunnel, between Miller's Dale and Buxton.

For a long time it was thought that the limestone of Derbyshire was readily divisible into the first, second, third, and fourth limestones. Whitehurst, Farey, and White-Watson considered that there were three beds of igneous rock, locally known as Toadstone, which were found throughout the limestone, making definite horizons in it and dividing it into four parts. Farey went so far as to attribute special characteristics to each of these limestones.

The following sections by Whitehurst and Farey, which are placed side by side for comparison, illustrate the divisions they made. Whitehurst's section is between Grange Mill and Darley Moor. Farey's is from Riber Hill on the east, to Masson Low, near Matlock Bath, on the west.

	WHITEHURST.	FAREY.
	Date, 1792.	Date, 1811.
	ft.	ft.
1st Limestone	150	150
1st Toadstone	48	60
2nd Limestone	150	150
2nd Toadstone	138	90
3rd Limestone	180	204
3rd Toadstone	66	90
4th Limestone	—	—
Total	732	744

Whitehurst inserts a band of clay between every two adjacent beds of the above section. Some thirty years ago, the officers of the Geological Survey considered that these formal divisions of the old geologists must be given up. Mr. Green wrote: "We should not be surprised to find lava-flows or deposits of volcanic ash very irregular in their occurrence, and all the evidence yet collected tends to show that, among the Toadstones of Derbyshire, some die out and others take their place on a different horizon."

The comparative sections given by the Geological Survey show that the beds of toadstone in different parts of the district cannot safely be identified. The beds passed through in mining-shafts prove that a bed of toadstone is present in one place and absent in another. This fact was known to the old geologists, who admitted that, in addition to the three beds, there were chance beds of toadstone. Recent work has proved Mr. Green's expectation to be correct, the igneous rocks undoubtedly being of limited horizontal range, and on different horizons in different localities.

Instead, therefore, of the igneous rocks dividing the limestone into four definite portions and enabling us to identify them in the different parts of the district, the stratigraphy of the limestone will have to be worked out in detail, both palæontologically and lithologically, before we can arrive at a complete sequence of the Derbyshire Carboniferous volcanoes.

Though the Carboniferous Limestone is distinguished by the number and variety of fossils which have been obtained from it, no attempt has been made to work out the palæontology of the different beds. Collectors have been satisfied with obtaining the fossils, and only in a few cases have noted the exact localities in which they occur.

Of the 500 species in the list made by the Geological Survey, the precise localities of only a small number have been ascertained, the remainder having no geographical value though known to occur in the Mountain Limestone of the county.

Productus, encrinites, and corals are perhaps more common than any other fossils. The Polyzoa are well represented. Amongst the Mollusca are numerous lamellibranchs, gasteropods and cephalopods. A few species of fish have also been found.

Productus giganteus is found in large quantities in the upper beds of the limestone, though it is by no means confined to them At Crich, a bed consisting almost entirely of this species occurs about 220 ft. below the top of the limestone. Corals are frequent in some of the lower massive beds in the neighbourhood of Miller's Dale, and are found in many localities. Encrinites are very numerous, and thick beds are often composed of the broken stems. At Monyash large slabs of encrinital limestone are

carried in what are probably upper beds of the Mountain Limestone. In the limestone above the bedded ash at Litton corals, crinoids, polyzoa, brachiopods, lamellibranchs and gasteropods have been seen. The beds in which they occur are at least 140 ft. down in the series. Although many limestone beds appear to the naked eye almost or entirely destitute of fossils, it is very seldom that numerous foraminifera have not been detected in them by the author when the specimens have been examined under the microscope.

Bands or wayboards of clay and also thin shale-partings occur amongst some of the massive beds. These wayboards are probably only local, although the miners have a strong belief in their wide horizontal range, and attempts have been made to identify them in different localities. A clay which sometimes occurs twenty fathoms below the toadstone is called the Twenty Fathom Clay by miners, but it would be impossible to identify clays of that name in different localities, unless we had evidence that the beds of toadstone under which they occurred were on the same horizon in each locality. Sometimes these clay-partings are numerous. An old section called a "vertical section of strata in the mineral liberties of Wirksworth," which is in the possession of Mr. Killer of Hoptonwood, near Middleton (who kindly allowed the author to copy it), shows no less than fifteen clay-partings in 700 ft. of limestone. Fourteen of these partings vary in thickness from one to six inches, and one attains a thickness of ten fathoms and diminishes to one fathom.

A thin bed of impure coal was found in the higher beds near Matlock Bath, and also in Combs Dale near Stoney Middleton. Calamites were found about 170 ft. below the top of the Mountain Limestone at Matlock Bath, and have been lately discovered by the author in a thin bed of shaly limestone, probably some 1,200 ft. down in the series, near Topley Pike.

Many of the limestone beds were formed in water comparatively still and free from mechanical sediment, but the shale and clay-partings found amongst the massive beds point to brief interruptions in these conditions.

The Mountain Limestone varies in structure, composition, and colour. It is often an almost pure carbonate of lime, white or light grey or blue in colour, and breaks with an irregular and sometimes conchoidal fracture. The dark grey and black varieties often contain bituminous and argillaceous material. Some of the beds appear to have originated from reef-like accumulations, like those of existing coral reefs and shell beds, others are more or less fragmental and formed of broken corals, crinoid stems, and brachiopods and other shells which have been spread out on the sea floor. Sometimes all traces of fossils have been obliterated by dolomitization and silicification of the lime-

stone and its contents. The fossils vary very much in the amount of detrition they have undergone. They are often very well preserved, so that the convolutions and spiral bases are clearly marked. In other cases they appear to have been much worn by water-action. The occasional occurrence of grains of quartz and of a previously consolidated limestone in the Carboniferous Limestone (though Derbyshire is not given as the locality) was pointed out by Dr. Sorby in 1879.

Since then, these water-worn fragments have been found to be common in the Mountain Limestone of Derbyshire. Mr. Wilson, in 1880, discovered, a short distance south of the Winnats near Castleton, an oolitic limestone containing water-worn pebbles of a more compact and darker coloured limestone. The pebbles varied in size from a pea to a bean and upwards, were usually more or less flattened, and lay with their flat sides roughly parallel with the bedding. Foraminifera were present in the rock and its pebbly contents. Three species, viz., *Valvulina palæotrochus*, Ehren., *Endothyra bowmanii*, Phil., and *Archædiscus karreri*, Brady, were found in this rock and in other beds in the neighbourhood.

In 1896 Messrs. Barnes and Holroyd discovered a sea beach of Carboniferous age which was well exposed in a quarry near the Speedwell Mine, Castleton. The rock was described by them as a conglomerate, the bulk of which was made up of water-worn shells arranged nearly parallel to the bedding planes. They also found rolled limestone pebbles in the upper limestone at Sparrow Pit and Windy Knoll, and at the latter place oolitic limestone. They conclude that the limestone at Castleton and in the immediate neighbourhood is a shallow water deposit. They have also traced somewhat similar beds in other parts of the limestone district. It does not, however, appear from their researches whether they have been able to obtain clear evidence of the bed being continuous from place to place. If such evidence were forthcoming, an object to be desired, viz., a datum line in the Mountain Limestone, would have been obtained.

It is quite possible, however, that detrital beds of this kind may be found at different horizons in the limestone, and that they do not extend for any great distance. Fragments of previously consolidated limestone, often containing foraminifera, have been found by the author in parts of the Mountain Limestone area, and on different horizons, and also in the Yoredale limestones. There seems little doubt that these detrital limestones have been formed at least in comparatively shallow water. The fragments of which they are composed must have been consolidated and broken up again before they were finally deposited.

The upper beds of limestone are generally thin, and contain numerous bands and lenticles of chert. In some places there is a second series of chert beds separated from the first by massive

limestones, and chert nodules are often found still lower in the series. The upper and lower surfaces of the chert beds and lenticles are seldom parallel, but have a wavy outline; nodular masses frequently branch off into the limestone above and below the parting of chert. The chert is sometimes in rows of isolated nodules roughly parallel to the bedding-planes of the limestone. Silicified corals, foraminifera and encrinite stems are often found in the chert, and the casts and stems of the latter fossils are locally known as "screws." Small rhombohedra of, probably, dolomite occur in the chert amongst the upper beds of limestone.

The Ashover Inlier.—About four miles north-east of Matlock is a small inlier of Mountain Limestone with an intercalated bed of volcanic tuff. An anticline passes through Ashover in a N.N.W. direction. The River Amber has cut its way along this anticline through the Millstone Grit, Yoredale rocks and part of the Mountain Limestone, into a bed of tuff which forms the bottom of the valley. The escarpments of grit are seen on both sides of the valley above the limestone. In a direction northwards from Ashover the succession of rocks from the limestone up to the Coal Measures are passed. According to Pilkington 240 yards of shale were sunk through in the Gregory Mine before the limestone was reached. A short distance east of the inlier the Trinity Chapel fault brings the Coal Measures against the various members of the Millstone Grit series. The upper beds of limestone contain *Productus*, encrinite stems, and layers and nodules of chert. The limestone near Westedge, N.W. of Ashover, and also near Hockley lime-kiln, is silicified and similar to the quartz rock found near Bonsall. Cubes of fluor are numerous on the joint faces of the limestone, and near Westedge are veins of the same minerals with slickenside surfaces.

The Crich Inlier.—Crich Stand, which is a tower on the summit of a limestone hill, 940 ft. above sea-level, and about two miles north of Ambergate Station, forms a conspicuous object for many miles. On the western face of the hill is a limestone quarry containing large blocks of rock piled confusedly one on another. The Mountain Limestone has been brought up by three faults and a bending of the strata, and the grit and shales above it have been carried away by denudation. This mass of limestone is about a mile and a-half in length, and about twice as broad at its N.W. end as at its S.E. It consists of an elongated dome, the main axis of which runs N.N.W. and S.S.E. On the east the beds dip gently under the Yoredale shales, but on the west are more highly inclined and bounded by a fault.

Fig. 2 is a section through Crich Hill from west to east. The toadstone intercalated with the Mountain Limestone is not marked on the section. The southern Crich fault has been traced from near Cromford by Lea Hurst and Coddington Park.

It brings the Mountain Limestone of Crich Hill against the Chatsworth grit of Coddington Park. Evidences of this fault are seen in the small cutting through which the tram-line runs from Ambergate to Cliff quarry. The line proceeds along the base of an escarpment of Kinder Scout grit, which is now being quarried, and just before reaching the village the grit is seen to dip W. and N.W., whilst a short distance further, in an old quarry near the main road through the village, the limestone dips nearly N.

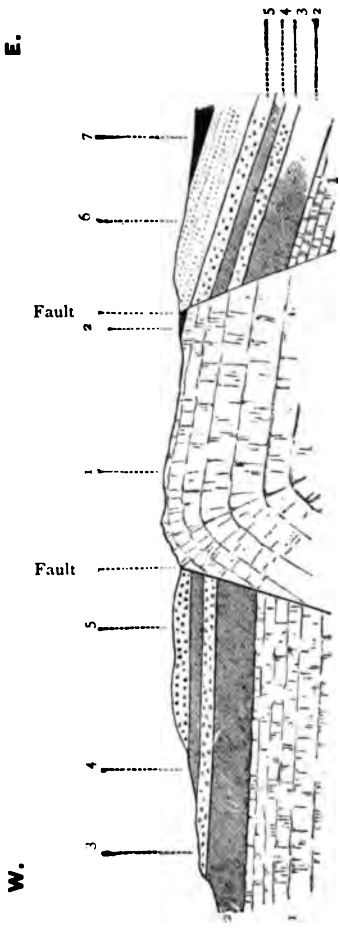

FIG. 2.—SECTION THROUGH CRICH HILL.—*Green.*

7. Coal Measures 5. Millstone Grit 3. Millstone Grit 1. Mountain Limestone
6. Millstone Shales 4. Millstone Shales 2. Yoredale Rocks

The western Crich fault bounds the limestone on the west of the inlier, and passes between the hill and the Kinder Scout grit of Wakebridge Farm. The limestones here are lower beds and abut against the shales, and the latter are to be seen dipping west at an angle of 60 degrees in the bank of the small stream near Wakebridge, a short distance from the old engine house.

The Trinity Chapel fault has been traced from near Ashover, through Trinity Chapel to Culland Wood. It brings the various members of the Millstone Grit series—viz., the Rough Rock and the Chatsworth and Kinder Scout grits—against the Coal Measures which lie east of the fault, and the Yoredale beds which lie above the Crich limestone east of the Stand, against the Rough Rock and its underlying shales.

The upper beds are cherty, and contain large quantities of *Productus giganteus.* They are exposed on the roadside south of the church in Hill's quarry and in Cliff quarry.

The following section is given by the Geological Survey:

1.	Thinly bedded limestones with chert [illegible]	[illegible]
2.	Thickly bedded limestone	[illegible]
3.	Wayboard of blue shaly clay	[illegible]
4.	Very hard massive white limestone	[illegible]
5.	Wayboard of clay	[illegible]
6.	Limestone	[illegible]
7.	Toadstone, averaging about	[illegible]
8.	Limestone, of which there was [illegible] in the [illegible] Mine, without reaching the bottom	[illegible]
	Total	[illegible]

The lower part of bed No. 2 is crowded with *Productus* and large blocks of limestone almost entirely composed of this fossil are seen in Cliff quarry. No. 3 is exposed in the quarry, and is a bed of black shale containing a few fossils. Its upper and lower surfaces are decomposed to a clay, and contain crystals of selenite, probably due to the decomposition of pyrites, cubes of which are plentiful in the less altered portions of the shale. The upper surface of the massive limestone, No. 4, underlying the shale, is worn into furrows and holes similar to those in the limestones below the toadstone in other parts of the district. The wayboard of clay No. 5 is the lowest bed seen in the quarry.

A lava-flow, contemporaneous with the limestone, is found some distance below the floor of the quarry and is only seen in the old lead workings. The author descended the Wakebridge mine some six years ago to examine the igneous rock from which lead ore was being obtained. The rock is a decomposed amygdaloidal olivine-dolerite traversed by veins of calcite and containing a large quantity of pyrites. It is interbedded with the limestones, and the gateway or level passes through it on both sides of the anticline. Near the entrance to the quarry and behind Cliff Inn the upper cherty beds with corals and *Productus* are seen. In the quarry are found barytes, dog-tooth spar, white, purple and yellow fluor, and small veins of galena.

Several landslips, due to the slipping of the limestone No. 2 on the bed of shale, have occurred from time to time on the north-west slope of the hill. In quarrying, the thick limestone which occupied the lowest part of the arch was removed. Consequently, those parts of the bed which lay nearer the centre of the dome, having no support and resting on an inclined plane of slippery shale, slid down towards the valley to the north-west, and carried away part of the road and a cottage. The effects of the last slip can still be seen in the quarry and on the brow of the hill near Crich Stand. The large blocks of limestone in the quarry have slipped from the hill-side above, and between the edge of the quarry and the stand the ground is traversed by

chasms or widened joints some yards across, and extending to a depth of about fifty feet.

Kniveton Inlier. — Between the villages of Bradbourne, Kniveton, and Hognaston, and about four miles north-east of Ashbourne, is an inlier of Mountain Limestone, the boundary of which has not been accurately determined, as the ground is often covered by drift and the beds are very much contorted. The upper thin limestones are seen near Bradbourne, where they pass regularly beneath the Yoredale shales, and in an old quarry east of New House. In the quarry about 30 ft. of limestone with thin shale partings are seen resting on massive limestone which dips at an angle of 60 deg. in an easterly direction. Chert bands are seen in an adjoining quarry, in Standlow Quarry, and east of Woodeaves Farm. Two faults were seen some years ago in Standlow Quarry, and are shown in a section given in the *Geol. Survey Memoir.* The massive limestones are seen in this quarry and on Wigber Low. Some of the limestone is dolomitized. The faulted boundary on the west of the inlier was marked on the Geological Survey Maps mainly to account for the irregular behaviour of the toadstone, on the assumption that it was inter-bedded with the limestone. The four faults form a quadrilateral figure, consisting mainly of Mountain Limestone with toadstone. The igneous rock is, however, a coarse agglomerate which cuts across the limestones, and the faults are therefore not required to explain its behaviour. Further work is required before it can be definitely settled whether any one of these faults is necessary to explain the limestone boundary.

Caverns.

Many of the caverns of Derbyshire are old lead mines, but others are natural and connected with the underground drainage of those parts of the district in which they occur. Amongst others the following caverns are shown to visitors: the Peak Cavern, Speedwell and Blue John Mines at Castleton, Poole's Hole at Buxton, and the Cumberland, Jacob's, the Roman, the High Tor, and the New Key Caverns at Matlock Bath. These, however, only form a small proportion of the whole. Many parts of the limestone district are literally honeycombed with them. The hills south of Castleton from near Mam Tor to Bradwell, and Masson Hill at Matlock are full of these underground passages.

The existence of unexplored caverns may be inferred by the lines of swallow-holes found in several parts of the limestone area. These holes in the limestone vary in depth and diameter, and have generally the shape of a wide cone with a blunted point at the bottom. The sloping sides are sometimes steep and generally covered with grass, with or without any sign of rock. The swallow-holes are formed by the action of surface water, finding its

way into joints, and enlarging them by dissolving away the rock, and ultimately emerging at a lower level and at some distance from the place of entry. As the volume of water increases, the subterranean course is enlarged by the solvent action of the water, and caverns are formed, the size of which is often augmented by the falling in of the roofs, and the partial or complete removal of the resulting *débris*. Swallow-holes are sometimes found in the toadstone. When a swallow-hole is formed in the limestone below a bed of toadstone, the latter falls in and the cavity is lined with it. If the toadstone bed is thin, it may be seen resting on the limestone below it, the two rocks forming the slopes of the swallow-hole.

The Speedwell Cavern, near Castleton, may be cited as an instance of those caverns which are partly natural and partly artificial. The entrance is near the bottom of the Winnats. The Speedwell level was made last century. It is at a height of about 700 ft. above the sea and 600 ft. below the surface of the hills through which it was driven. The object in making it was to reach some of the rakes which run through the hill. It is said that the total length of the level is about 1,350 yards. At a distance of 750 yards the level reached the New Rake which was found to have been hollowed out into a large swallow-hole or narrow cavern, extending a long distance upwards and to a great depth downwards. It is estimated that 40,000 tons of rubbish from the driving was thrown into this chasm, now called the "bottomless pit," without any visible effect.

In Mill Close Mine, near Darley Dale, caverns are found along or branching off the main vein. They sometimes attain a great size, and several are often connected together. Many of these large cavaties are rich in ore and lined with dog-tooth spar and cubes of galena.

The Blue John Mine is another instance of large underground cavities connected by artificial passages. It is supposed to have been discovered accidentally in some mining operations by the Romans. It is situated in Treak or Tray Cliff, near Windy Knoll and the top of the Winnats south of Castleton. The northern portion of the main mass of Mountain Limestone is here cut off from the Yoredale shales by faults on the north, west, and east. This cavern was carefully examined by Messrs. Barnes and Holroyd, and the following brief particulars are taken from their description: The entrance to the mine is by means of an artificial opening, which soon leads to a natural passage 28 ft. in height. The mine consists of a series of natural passages and caverns connected by artificial passages. These cavities are known by various names. A swallow-hole, 49 ft. deep, with numerous pendant stalactites, is passed through. The level path called the Ladies' Walk leads to the Grand Crystallized Cavern, which is 60 ft. long, 13 ft. wide, and 45 ft. high. Lord

Mulgrave's dining-room, 39 ft. by 36 ft. and 57 ft. high, is in the form of a rhomboid in vertical section. The floor is artificial, the real bottom being far below. Underneath the floor is a stream of water. The walls of the Variegated Cavern are lined with dog-tooth spar. In the two latter caverns are many large blocks of limestone which have fallen from the roof. The New Cavern is 100 yds. long and 16 yds. wide, and is described as the "largest, the wettest, the dirtiest, and the most rugged and irregular" of any of the series. This cavern leads to the Fairy Grotto, a small cavity 17 ft. by 13 ft. and 20 ft. high, with sparkling carbonate of lime covering the walls and floor and forming delicate stalactites and stalagmites. The distance from the entrance to the Variegated Cavern is 300 yds., and the vertical descent 220 ft. The total distance of the winding passages is said to amount to over three miles. Some curious curved and upturned forms of stalactites were found and called by the authors *anemolites*. They were considered to be due to currents of air blowing the water to one side or in an upward direction, and causing more rapid evaporation and deposition of carbonate of lime on one side than on the other. Blue John is a banded variety of coloured fluor-spar, and is largely worked into ornaments. It occurs in veins, nests, and fissures, and as nodules in the limestone. Barytes and calcite are associated with it.

The Peak Cavern at Castleton, the entrance to which is by far the finest part, is another good example of a natural cavern connected with a system of underground drainage. This cavern drains the district immediately west and south-west of the village. The water enters the limestone along a line of swallow-holes from Perryfoot to Windy Knoll, near the boundary of the Mountain Limestone and Yoredale Shales. At Perryfoot a small stream disappears down a hole in the limestone. The course of the underground water was identified more than a hundred years ago. It is seen in the Speedwell level running east, and finally discharges partly through the cavern, but largely by a spring near its mouth called Russet Well, and flows down the valley, joining the river Noe near Hope. Part of the water is probably derived from the hills further south. Eldon Hole, a chasm near Peak Forest village, may also communicate with the cavern. It is reported that a goose which fell down Eldon Hole emerged at Castleton.

Another system of underground drainage occurs near Eyam. The water enters by swallow-holes, notably by one formed at the intersection of two veins near Foolow, and finds its way to the valley of the Derwent by way of Middleton Dale. The disappearance of the water often results in a dry valley which represents the old watercourse. Linen Dale, near Eyam, is one of these valleys. Great Rocks Dale, through which the Midland Railway passes between Miller's Dale and Doveholes, is another

dry valleys. From particulars given by Mr. Barnes, the engineer of the line, it appears that great difficulties were encountered in diverting a brook which disappeared down a swallow-hole near Doveholes. In a quarry near the south end of the tunnel the flow of underground water was distinctly audible, and at a depth of 30 ft. a very considerable stream of water was flowing from the direction of the swallow-hole. A channel was cut near the swallow-hole in the direction of Great Rocks Dale. The water ran along the new course to a point half a mile south of the tunnel, where it disappeared down a fissure, into which it flowed for six months. It then resumed its course along the channel provided for it, and found another fissure near Peak Forest Station, into which it was running as late as 18[illegible], and from which it is believed there is an underground outlet down the Great Rocks Dale. The length of the artificial channel is nearly two miles.

The underground drainage in the Limestone district has been considerably modified by the numerous "soughs" which have been driven through the rock in order to carry away the water met with in the workings and thereby save the expense of pumping. Meerbrook Sough, which empties itself into the Derwent near Whatstandwell, is nearly three miles in length. It drains several mines in the neighbourhood of Wirksworth. A few years ago a suggestion was made to utilise the water from this sough in order to supply the town of Derby. This idea was abandoned, and at the time of writing this sketch Derby, Leicester, Nottingham, and Sheffield are endeavouring to obtain powers to impound the waters of the upper Derwent and its tributaries. If these powers are granted the result will be a series of reservoirs which will materially alter the appearance of Edale and the valleys of the Ashop and Derwent.

It has already been mentioned that some of the gorges or dales have been formed by the falling in of the roof of underground caverns. The short gorge at the very fine entrance to Peak Cavern, and the gorges known as the Winnats and Cave Dale, the latter of which has a very narrow gorge-like opening at its lower end, have probably been formed by underground streams and the denudation or falling in of the roofs of caverns.

Some of the caverns at Matlock are well worth a visit, but it is unnecessary to enter into any details concerning them, as they are mostly continuations of old lead mines and watercourses, and have been formed in a similar way to those at Castleton. We must, however, mention the so-called caverns in the High Tor. These roofless caverns consist of almost vertical fissures in the limestone, and are probably joints which have been enlarged by water-action. The fissure called the Fern Cavern runs N.N.W., and is nearly parallel to the precipice of the High Tor. It is about 600 ft. long, 150 ft. deep, and in places reaches a width

of 2 ft. Apparently it once extended further in the direction towards Matlock Bridge, since the eastern wall of the fissure produced, forms the face of the present cliff which bounds the valley. A diagram sketch of this fissure is found in the *Geol. Survey Memoir*, on p. 101. The Roman Cavern consists of a smaller fissure, which runs nearly parallel to the strike and to the boundary between the limestone of the High Tor, and the Yoredales and grits of Riber Hill.

Lead and Lead Mining.

The Odin Mine near Castleton is probably the oldest in the county and is reputed to have been worked by the Danes. The discovery of pigs of lead with Latin inscriptions proves that lead ore was raised and smelted in Derbyshire during the Roman occupation. The mines at first appear to have belonged to religious houses and eventually passed into the hands of the Crown. Curious customs and rights connected with the mining of lead have been in use from time immemorial, and these were confirmed to the miners by two Acts of Parliament passed in 1851 and 1852. The following short quotations from Mr. Stokes' exhaustive paper on the early history of lead mining in Derbyshire will give some idea of these customs: "All subjects of the realm may search or dig for lead ore in or under any person's land (without even asking permission of the owner of the surface), and providing the miner finds ore and frees the mine by paying one dish to the Barmaster. He then claims and is entitled to sufficient surface or land for his hillock or spoil heap, a way for foot-passengers or carts from the highway lying most convenient to the mine, and also waterway to the nearest running stream of water. The owner or occupier of the land over which these things exist cannot claim any compensation." "The only compensation the landowner gets for all this annoyance and loss of surface is the right to sell and dispose of all and every other mineral raised by the miner except lead ore."

Dues were paid to the Crown, the Duchy of Lancaster, the Barmaster, and in some places to the Church of the district. The royalty to the Crown was so much per dish, a dish containing about 472 cubic inches. The tithe which was often disputed "is said to have arisen from the assertion that the ore grew and renewed in the vein."

The lead ore which has been mostly worked is known as galena or sulphide of lead. It contains a small quantity of silver (two to four ounces per ton). Cerussite or carbonate of lead, called also white ore, is found in crystals lining cavities in galena, and is supposed to be an alteration or decomposition of the sulphide. Mimetite (brown lead ore), pyromorphite (green lead ore), and

phosgenite (yellow lead ore) are also found in small quantities, but the latter two only as cabinet specimens.

The ore occurs in Rakes, Pipes, and Flats. A rake vein is generally an almost vertical fissure or crack in the limestone. When the fissure is due to a fault the walls often have a slickenside surface and the beds on either side of it have suffered displacement. Scrins are strings of ore which branch off from the rake and form smaller veins. The ore occurs in ribs with layers of calcite, barytes, or fluor arranged more or less parallel to the walls of the rake. Sometimes it is found in isolated cubes or assemblages of cubes of galena with calcite or barytes.

Pipe veins are irregularly shaped cavities or pockets in the limestone generally parallel to the bedding planes, and often connected with one another by a crack filled with clay or spar, called a leader. They vary considerably in size, and may be considered as the widening out of a rake or scrin. The ore in them is often found in lumps mixed with blocks of limestone, barytes, calc-spar, and clay. This mixture is apparently due to the falling in of the roof of a cavern lined with these minerals.

A Flat is not so common as the rake and pipe veins. It is generally found along the junction of two beds, and consists of a low flat chamber with the roof and floor only a few feet apart, and seldom has any leaders connected with it.

The lodes are richer and more numerous in the upper than in the lower beds of limestone, and most of the rich deposits of ore have been found in the beds immediately below the Yoredale shales. It has often been stated that the toadstones are unproductive of ore, and it was contended that the vein was cut off by the igneous rock, and therefore that the latter had been intruded between the limestone beds after the vein was formed. In some cases a vein on entering the toadstone becomes broken up into a number of strings of spar, or changed into a thin leader of calcite. But the ore was undoubtedly worked in the toadstone in the Seven Rakes Mine, near Matlock, and in the Wakebridge Mine, near Crich. The author visited the workings of the latter mine, and saw some fine cubes of galena in the toadstone. Though some of the toadstones are contemporaneous with the limestone, others are intrusive and later than the beds in which they occur. The intrusive sheets and vents if later than the formation of the veins would undoubtedly cut them off.

The large number of old lead mines bears witness to the great amount of mining which has been done in Derbyshire. But of late years only few mines have been worked. The majority have been worked out or abandoned because of the incapacity of the owner to continue through the difficulty of getting rid of water or the expense of obtaining the ore, and not least because of the considerable fall in the price of lead. The Wakebridge workings were continued until a few years ago, and ore has lately been obtained

near the surface at Monyash. But the only mine at which lead is being raised at the present day is the Mill Close, near Darley Dale. It was abandoned for 100 years and re-opened in 1859 by the late Mr. Wass. Since then a large quantity of ore has been obtained. It is in the upper beds of the Mountain Limestone.

Small quantities of copper ore, black oxide of manganese (commonly known as wad), hæmatite, yellow and red ochre, have been worked in the limestone; heavy spar or caulk (barytes), used in the manufacture of white paint, has of late years been obtained in the old hillocks. A stalactitic form of barytes was found near Youlgreave.

Fluor-spar (calcium fluoride) is found in small cubes lining fissures in the limestone, and has been worked at Ashover. "Blue John," the purple variety arranged in layers of different shades of colour, is found at Castleton. Calc-spar is abundant in veins, and is crushed and used for making footpaths. Bitumen is found only in small quantities and in two forms. The brittle variety may often be seen filling small cavities in the limestone and the interior of fossils. It is black and hard, and has a shining surface when fractured. The softer variety known as elaterite is elastic and adheres to the fingers, but is sometimes soft like indiarubber. It is black and dark brown. Both kinds occur in Windy Knoll quarry, near Castleton, The following analysis of the elastic variety from Derbyshire was made by Prof. Macadam:

Carbon	83·624
Hydrogen	11·186
Oxygen, &c.	4·781
Nitrogen	0·172
Sulphur	0·237
	100·000

Metamorphic Limestones.

Contact metamorphism, due to the intrusion of igneous rock, is seen in some of the limestones in contact with the sills. The limestone above the sill at Peak Forest is rendered saccharoidal to a distance of 5 ft. from the junction, whilst that below the sill in Tideswell Dale has been altered to a distance of 12 ft., and a clay has been baked to a distance of 9 ft. from the junction. The saccharoidal or marmorised limestone is easily distinguished from the ordinary more or less crystalline variety of limestone with fossils which is found in many localities. When completely marmorised, it is crystalline, hard and brittle, and breaks with a powdery and saccharoidal fracture, and all traces of fossils are often obliterated. Pieces of marmorised limestone are found in the agglomerate of necks. This metamorphism cannot always be traced in the neighbourhood of the intrusive rocks. Some of the sills and necks, although they show undoubted traces of cutting across the beds, have not

effected an alteration in the limestones through which they have passed, unless it be at the actual junction, which is hidden from view. Even in the neighbourhood of the two large vents at Grange Mill, the limestones, though to some extent crystalline, cannot be said to be marmorised, and many of the small rounded lumps of limestone found in the agglomerate of vents and in bedded tuffs are quite like ordinary limestone.

Dolomitized limestone (locally known as Dunstone) is found in many parts of the district, but appears to be mainly confined to the southern portion. Some of the beds are almost pure dolomite, and in them the organic structure, if ever present, has been entirely obliterated. It forms thick beds on Masson Hill, which are well exposed on the hill slopes and in the Cumberland Cavern at Matlock Bath. Near Hopton and Brassington, along the course of the High Peak Railway, it is apparently present as a bed in the Mountain Limestone, the thickness of which has been estimated by the Geological Survey officers at 400 ft. It weathers into castellated outlines, such as those at Harbro' Rocks and along the slopes of the valley leading from Longcliffe Wharfe to Bradbourne Mill, and presents a marked contrast to the white limestone of the district. It has a rough and often knotted weathering; the surface is frequently pitted with small holes, and some specimens contain hollow moulds of encrinite stems. It is also found north of Grange Mill; and in the neighbourhood of Winster crosses Gratton Dale, where it is interbedded with the limestone, dipping N. at an angle of 20 deg., and attains a thickness of about 450 ft. Below the thick bed in this Dale, and separated from it by about 20 ft. of ordinary limestone, is another dolomitic limestone, the whole thickness of which is not visible. It is probable that these two almost parallel outcrops of dolomitized limestone once formed parts of the same bed in the dome of limestone of which Grange Mill is the centre. Both beds are about the same depth down in the series. The Hopton bed, according to the Geological Survey Section, is more than 600 ft. below the top of the Mountain Limestone, and according to the author's measurements, the Gratton Dale bed is 700 ft. below the limestone boundary at the bottom of Gratton Dale.

The dolomitized limestone also occurs on a much smaller scale. Sometimes the dolomitisation has proceeded along joints in the limestone; at others part of a bed is altered, and the remainder consists of ordinary limestone. When weathered, the dolomitized limestone has a rough, gritty surface, and decomposes into a soft gritty sand, which may be seen in some new workings between Longcliffe and Grange Mill. Some of the thin dolomitized limestones, especially those occurring in the Yoredale shales, might easily be mistaken for sandstones on the weathered surface.

Silicified Limestone or Quartz Rock is found in blocks on the

surface of the ground at Batham Gate, Brock Tor, and Oxlow Rake, near Tideswell, and in other localities. At the head of Pindale, these blocks are large and numerous, and sometimes contain small quantities of chert. The rock occurs in irregularly shaped bosses on Masson Hill, near Matlock (see Map, Plate III), and at Ashover. Its microscopical composition and its relation to the limestone beds show that it is a limestone which has been entirely converted into crystalline silica. It consists of quartz crystals, often elongated and interpenetrating one another, forming an aggregate of quartz grains. It is not formed of detrital grains cemented together by secondary quartz, but has originated by the crystallisation of the quartz in such a manner that adjacent grains have prevented their neighbours from assuming crystalline boundaries. It frequently contains fluor; associated with it is a quartzose limestone, *i.e.*, a foraminiferal, and sometimes an oolitic limestone, containing a large proportion of quartz in individual crystals and bunches of crystals, like very minute portions of the quartz rock. Small veins of similar structure also traverse the quartzose limestone, and the latter is often found in small lumps inside the completely silicified rock. There is a gradual passage from the quartz rock through the quartzose limestone to an ordinary limestone, which contains few, if any, crystals of quartz. This mineral, therefore, is present in some parts of the limestone as numerous separate crystals, in groups of crystals, and on a larger scale as veins and bosses of quartz rock, and a common origin must be ascribed to the quartz in the quartzose limestone and in the quartz rock. The presence of chert in the quartz rock of Pindale and part of a foraminifer in the similar rock of Pounder Lane, and the frequent penetration of organisms by quartz crystals in the quartzose limestone appear to be sufficient evidence of the quartz rock being a replacement of limestone. In cases such as at Top Lift the whole of the limestone and quartzose limestone have been weathered away, leaving the quartz rock in bosses or loose blocks. In others, patches of the softer rocks are left which show the transition from an ordinary limestone to a completely silicified rock.

Yoredale Rocks.

The Yoredale rocks of the Geological Survey include the sandstones, shales and limestones which lie between the lowest Millstone Grit and the Mountain Limestone. They were originally divided into the following three groups, and are mapped as such on the 1-inch Geological Map:

UPPER YOREDALES.	Yoredale or Shale Grit, with shale and thin sandstones above and below.
MIDDLE YOREDALES.	Yoredale sandstones, with beds of black shale.
LOWER YOREDALES.	Black shales, with thin beds and nodules of earthy limestone.

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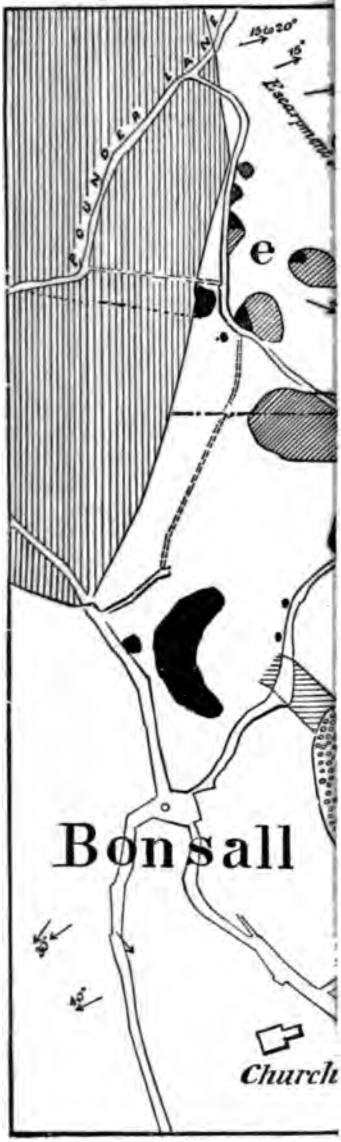
Map of District N.E.

Shewing distribution of



Mountain Limestone

Quartz Rock.

Quartzose Limeston

Feet

(*Reprinted b*

To face page 180.

It was found that in Derbyshire there was a lithological difference between the Kinder Scout and Yoredale Grit, but that further north these distinctions vanished. The classification was therefore modified, and in the second edition of the Memoir the Yoredale Grit was transferred to the Millstone Grit group. At the same time the term Yoredale Grit was abandoned and Shale Grit was substituted for it. So that the Yoredale rocks at present consist of two divisions, viz., the sandstones with shales and the shales with limestones. This classification was considered to be provisional, and one convenient to be retained. The Yoredale sandstones were looked upon as "passage beds deposited irregularly in the interval during which the change took place from the marine conditions of the Carboniferous Limestone series to the freshwater or estuarine condition of the Millstone Grit and Coal Measures." Lithological characters were the only guide since no fossils had been found in the Yoredale Sandstones. The difficulty of drawing a line between these sandstones and the shales and limestones below them was pointed out. There seems to have been a doubt whether the Yoredale sandstones mapped in Edale and about Bamford are the equivalent of the Yoredale sandstones of N. Staffordshire, or whether they ought to be included in the Shale Grit. South of Hathersage the thin limestones and shales are generally found immediately below the Shale Grit.

Dr. Wheelton Hind considers that the Yoredale rocks of Wensley Dale are the equivalent of the upper part of the Carboniferous Limestone, and that the Yoredale beds of Derbyshire are a different series and occupy a position above the Carboniferous Limestone. He proposes to divide the Carboniferous rocks into an upper and lower series, the upper one to include the Coal Measures and the grits and shales below them, the base being drawn at the uppermost thin limestone. The lower group to include the shales with thin limestones and the Mountain Limestone. He would restrict the term Yoredale series to the district of Wensley Dale. He claims that this binary division is based solely on biological grounds. It appears then that Dr. Hind draws the boundary between the Upper and Lower Carboniferous rocks at the base instead of at the top of the Upper Yoredales. If we consider the Yoredale sandstones of the Geological Survey to belong to the Millstone Grit series (which in the case of Derbyshire the writers of the memoir seem to think is probably the correct view) the Yoredale rocks of Derbyshire will then include only the limestones and shales which lie above the Mountain Limestone. Dr. Hind's boundary and that of the Geological Survey thus practically become one and the same for Derbyshire, and the only point in dispute appears to the author to be the use of the word Yoredale. Whatever may be the ultimate fate of the term, the author has as a matter of convenience followed the nomenclature of the

Geological Survey and retained the use of the word in this Sketch.

The black shales and thin limestones of the lowest division of the Yoredale Rocks vary in character and thickness in different parts of the county. In Edale they consist of shales with nodules of limestone containing *Goniatites*. At Cromford, the limestone forms short lenticular beds in the shale. In other places the limestone is in thin beds intercalated amongst the shales, and the proportion of limestone to shale varies greatly. About 36 ft. of alternating limestone and shales in the railway cutting at the east end of Monsal Dale were recorded by the Geological Survey. They rest on the cherty beds of the Mountain Limestone. The thin limestones amount to a little over one quarter of the whole, the remaining three-quarters consisting of shale. Near Ashbourne, the limestones are evenly bedded, become more numerous, and closer together, so that it is often difficult to say whether they should be placed at the base of the Yoredales or at the top of the Mountain Limestone. They often contain chert, encrinites and *Productus*, and are frequently dolomitized, and cannot be distinguished petrographically from some parts of the Mountain Limestone. These beds are seen in the neighbourhood of Kniveton, and in nearly every case are contorted. But perhaps the best exposures, which give evidence of the numerous folds into which these beds have been thrown, have been laid open recently in the construction of the new L. & N. W. Ry. from Buxton to Ashbourne. In the cutting in which Tissington Station is situated, the shales and limestones are seen to have been bent into about six anticlines, and the same number of synclines in a distance of 300 yards, and only about 90 ft. of shales and limestones are seen. Though several limestones have been traced through this part of the cutting, others are very inconstant and soon thin out. They contain chert bands, *Productus*, encrinite stems and fish teeth. Some are dolomitized, others are black and similar to the upper beds of the Mountain Limestone. Plate IV, Fig. 2, gives some idea of the contorted strata seen in the cuttings. Further reference to these beds will be found in the remarks on the igneous rocks.

No reliable estimate of the thickness of the Lower Yoredale shales has been formed, because the beds roll about so much, especially in the north and south-western part of the district. Between Eyam and Matlock several lead-mining shafts have been sunk through them, and proved that they are at least from 300 to 400 ft. thick. According to the Geological Survey the two groups forming the Yoredale series are at least 400 or 500 ft. thick, and may reach even 1,000 ft. Very little information seems to have been obtained about the Yoredale sandstones which form the upper group. It has already been stated that the sandstones in Edale, which are mapped as Yoredale, may

FIG. 1.—BASALT AGGLOMERATE, IN VOLCANIC VENT, HOPTON, NEAR WIRKSWORTH.

FIG. 2.—SYNCLINE AND ANTICLINE IN YOREDALE SHALES AND LIMESTONES. L. & N. W. RLY. CUTTING, TISSINGTON, NEAR ASHBOURNE.

(From Photographs by H. Arnold-Bemrose.)

possibly belong to the Shale Grit. In places farther south they are absent altogether, the Shale Grit resting on the Yoredale limestones and shales.

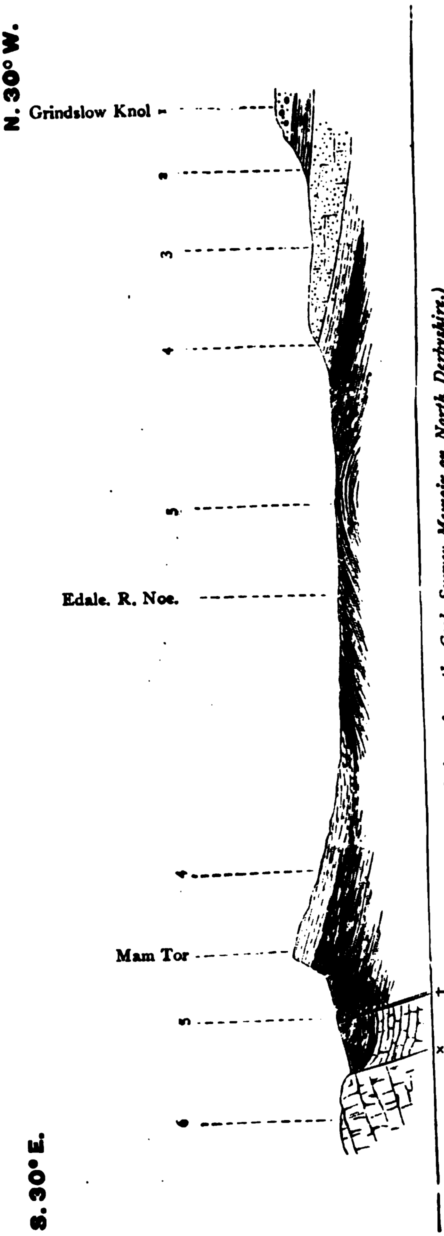
Millstone Grit.

The Millstone Grit series of Derbyshire consists of five thick sandstones parted by shales with which thinner sandstones are interbedded. These grits vary in character from a fine-grained sandstone to a conglomerate, and consist mainly of quartz, orthoclase-felspar and mica (muscovite). According to Dr. Sorby, they have been derived from the disintegration of older rocks, such as granite and schist, and have been deposited by currents from the north-east. Traces of coal are found on the top of each of the five sandstones.

The Fifth, or Shale Grit, so called by Farey because of the intercalated shales it contains, consists of thick massive sandstones, hard and close-grained, passing often into a conglomerate. The intercalated shales are inconstant and when traced some distance are found to die out, and others to make their appearance. It attains a thickness of 500 or 600 ft. around the Peak, thinning away to the south and being absent in some places. Round the Kinder Scout grit of the Peak, the Shale Grit forms a broad plateau which is deeply channelled by rivers and brook courses. The outcrops of the shale bands are marked by small terraces which run along the steep sides of the valleys. Along the course of the River Alport are numerous landslips, the largest of which is called Alport Towers, formed by masses of the Shale Grit which have slid down from the hills above. South of the Peak the Shale Grit caps the ridge between Lose Hill and Mam Tor. The beds dip north, and farther south, at Castleton, we come to the Mountain Limestone. The River Noe, which runs down the Edale valley, has cut down into the plateau of Shale Grit to the Yoredale Limestones. The arrangement of the beds is shown in Fig. 3, which is a section across Edale and the Castleton Valley, from the *Geological Survey Memoir*. An anticline ranges along the north flank of the valley and on the north side the Yoredale rocks are brought out by the southerly rise of the beds. Some good sections are given in the "cloughs" which run down from Kinder Scout into Edale. The following is an average section by the Geological Survey:

		ft.
MILLSTONE GRIT.	Sandy Shale below the Kinder Scout Grit ...	290
	Shale Grit	425
YOREDALE ROCKS.	Supposed representatives of the Yoredale Sandstones...	200
	Black Shales and nodules and beds of Earthy Limestone...	—

On the south flank of the valley there are few sections, except along the river Noe. At right angles to this anticline another



(*Reprinted, by permission, from the Geol. Survey Memoir on North Derbyshire.*)

Scale, two inches to one mile.

FIG. 3.—SECTION ACROSS EDALE AND THE CASTLETON VALLEY

1. Kinder Scout Grit }
2. Shales } Millstone Grit
3. Shale Grit }
4. Yoredale Sandstones }
5. Black Shales and thin Limestones } Yoredale Rocks
6. Lower massive white Limestones, Mountain Limestone

× Fault. † Odin Lode, probably a fault down to the North

one runs through Edale Chapel and Mam Tor in a N.W. and S.E. direction. If produced it passes through the middle of the limestone district; and it has been considered to mark the direction of the Pennine upheaval. A dome-shaped mass of the Lower Yoredale beds is brought up in the middle of the valley, and the Yoredale sandstones of Mam Tor are raised higher than the Shale Grit of Lose Hill.

In the scarped face of Mam Tor, about 200 ft. of what are considered to be Yoredale sandstones are seen. In the shales intercalated with them Dr. Wheelton Hind found *Goniatites* and *Posidoniella*. At the foot of the Tor the lowest division of the Yoredale rocks are found to rear up on end, and are faulted against the Mountain Limestone near the Blue John mine. Mam Tor is called the shivering mountain, owing to landslips which have taken place. A great part of the hill has fallen, and carried away with it a portion of a Roman entrenchment.

The Fourth, or Kinder Scout Grit, consists of two thick beds of sandstone separated by shale. The lower one—a coarse grit and conglomerate—dies away on Bamford Edge, and is not found further south. The upper one varies from a coarse grit to a fine grained sandstone. The Kinder Scout grit generally forms bold craggy cliffs surmounted with piles of rock weathered into fantastic shapes. Robin Hood's Stride and the Rowtor rocks, near Rowsley, are formed of this grit. The Black Rocks is the name given to an escarpment of the Fourth grit near Cromford, along the base of which the High Peak Railway runs.

Mr. Mello considers that the "bosses of rock and tabulated stones," near Edale, "have a wonderfully close resemblance to sea shore rocks," and that the inland cliffs of the Black Rocks and Kinder Scout are outliers of grit which have "escaped being carried away by the wear and tear of the sea," and that the bold cliffs of Kinder "still bear in the rock basins and hollowed faces so frequently present marks of that time when the salt waves dashed against it and wore it into its present shape."

It appears more likely that these results are due to the effects of subærial denudation. The grit is underlain by shales, and dips into the hill near Cromford and at Kinder. As the softer shales are removed the grit falls down in blocks and an escarpment is formed. The undercutting of the bosses of rock, such as are found on Kinder, were considered by Sir A. Ramsay to be due to the denuding action of loose sand (produced from the weathering of the grit) being blown by high winds against the isolated bosses of rock.

The Third or Chatsworth Grit varies greatly in character. In the centre of the district it is a coarse conglomerate, and becomes a fine-grained sandstone as it is traced north and south. It is often called the Escarpment grit. The broken edge of its

outcrop forms long escarpments, which often run for miles along the country and make a distinctive feature.

The beds between the Third and First Grits are very changeable, and made up of shales with sandstones which vary in thickness and horizontal extent, beds of gannister, and thin coals.

The First or topmost Grit is known as the Rough Rock, and is the most constant of the series in thickness and character. It is described as a massive coarse grit with a large proportion of felspar, the decomposition of which makes the rock loose and crumbly. Its average thickness is 100 ft.

The terraces or escarpments formed by the various grits are seen along the line of Horizontal Section, No. 69, of the Geological Survey. The entire series is crossed from the Lower Coal Measures on Ughill Moors to Derwent Chapel.

Miscellaneous.

SANDS AND FIRE CLAYS IN THE MOUNTAIN LIMESTONE.

Deposits of coloured sand and clay, with quartzite pebbles, occur in pockets or irregular hollows in the limestone in the neighbourhood of Newhaven and Brassington. They are situate on a line running in a direction from N.W. to S.E. for a distance of about seven miles from near Hartington, on the N.W., to Brassington, on the S.E. In addition to smaller pits, larger ones have been worked at Newhaven, Minninglow, Longcliffe, Harbro, and Brassington. The clay from the latter place was worked previous to 1789, and sent to Derby Porcelain Works. These hollows in the limestone, which may represent swallow-holes, reach as much as 100 yards across. The deposits consist of a very fine clay and clean sand, the lines of division between them often being nearly vertical. The sand is sometimes bedded in the form of a basin, that in the centre of the pit being nearly horizontal, and that near the edges dipping steeply away from the limestone which forms the sides. At Newhaven and Longcliffe, the removal of the sand and clay has brought to view the weathered upper surface of the limestone, which forms part of the walls of the pit. The clay and sand are sometimes white, and at others coloured red and yellow. The sand contains many quartzite pebbles, which are generally white, but sometimes red.

Various explanations of the origin of these deposits have been given. The presence of quartz pebbles was considered by the Geological Survey officers to denote that a portion at least was derived from the Kinder Scout grit, and it was supposed by them that a large part of the material was due to the decomposi-

tion of chert and sandy or argillaceous limestone, and that the hollows, as in the case of the similar Welsh deposits, were filled in pre-Glacial times. The origin of the sands and pebbles has also been attributed to the Bunter Beds. However much opinions may differ about the origin of the deposits, there is no doubt that they are pre-Glacial. Mr. Deeley and the author have found undoubted proof of this in the case of one of the pits.

An examination of the sand shows that it consists of small, well-rounded grains of quartz, unlike the angular grains found in the Kinder Scout grit. If, therefore, it has been formed from that rock, it must have been subjected to such an amount of trituration as would convert the angular into rounded grains. The author found lately, in one of the hollows near Brassington, a piece of reddish-coloured grit, with quartz pebbles imbedded in it. Without microscopic examination it is unsafe to say whether it is from a bed of Millstone Grit or a portion of the sand solidified and hardened *in situ*.

Glacial Drift.

The drift deposits of the lowlands of Derbyshire have been fully worked out by Mr. R. M. Deeley, but very little has been done at those in the hill district included in this Sketch. Mr. Deeley is extending his researches to this part of the county, but has not yet published any results. The following is a very brief summary of what has been observed by the Geological Survey and by the author. Deposits of clay containing striated limestone boulders, large pebbles of grit, and a few boulders of foreign rocks are found in the valley of the Wye, at Monsal Dale, Longstone, Baslow, Haddon Hall, and Youlgreave, and on the flanks of the Derwent Valley near Matlock and Crich. Thick deposits of Boulder Clay were found in the five cuttings in the L. & N. W. Railway between Ashbourne and Tissington. The clay contained numerous boulders of well-striated Mountain Limestone, of grit, sandstone, shales, chert, and igneous rocks foreign to the county. At Spital Hill, a short distance south of Ashbourne, a well boring passed through 50 ft. of clay with large limestone boulders, and 20 ft. of running sand.

Pleistocene Mammalia.

Many Pleistocene Mammalia have been discovered in caverns and fissures in the Mountain Limestone. Elephant remains were found at Balleye, near Wirksworth, and in a fissure at Doveholes, and a rhinoceros tooth was found at the entrance of Peak Cavern. In a cave near Matlock, rhinoceros, cave hyæna, bear, reindeer, fox, red deer, and bison were discovered, and in Harth

Dale remains of rhinoceros, bison, and mammoth. At Windy Knoll, near Castleton, bones of bison and reindeer, with grizzly bear, wolf, fox, hare, rabbit, and water vole, were obtained by Mr. Rooke Pennington from a swallow-hole in the Mountain Limestone. A cavern in Cave Dale contained bones of recent fauna, as well as relics of human occupation.

Calcareous Tufa and Stalactitic Deposits.

These deposits are due to the solvent action of water charged with carbonic acid on the limestone. As the water evaporates, the carbonate of lime which has been dissolved is re-deposited as beds of tufa, and in a cavern the drippings from the roof form stalactites and stalagmites. The tufa consists of amorphous carbonate of lime, which has often been deposited around twigs, leaves, moss, shells, and bones of animals. Large deposits of this rock have been formed by the warm springs at Matlock. Above the right bank of the Derwent it reaches a thickness of 30 ft., and is at the present time well exposed near the New Bath Hotel, which is built upon it. At Matlock, and in the Via Gellia, it is quarried for ornamental rock-work, and has been used in the construction of a house in the latter valley. That some parts at least are of recent origin is shown by the finding imbedded in it a Roman or Saxon iron spear-head by Mr. Mello. Proofs that it is being formed at the present day also are numerous at Matlock and in many parts of the limestone district. Two of these only need be mentioned. On the southern slope of Miller's Dale a spring issuing from the top of the toadstone bed has covered the face of the dark-coloured igneous rock with a thick crust of tufa, and in Monk's Dale a stream is forming small terraces of tufa with basins like the New Zealand sinter terraces on a small scale. The petrifying springs at Matlock Bath which issue from the limestone form deposits of calcium carbonate on the small objects placed in them, and along their short course into the river are forming tufa.

Warm Springs.

Owing to the readiness with which the surface waters make their way down into the limestone it is not surprising to find that many parts of the area covered by this rock are destitute of water. Were it not for the beds of toadstone and the clay partings which are impermeable to water there would be no springs on the limestone hills at any height. Many of the springs issue from the top of a toadstone bed, the upper surface of which may often be traced at points along the line of its outcrop. Several springs flow from the top of the bedded ash near Grange Mill. Dunsley spring, which runs down into the Via Gellia, Five Wells

and other springs near Taddington flow from the upper surface of toadstone beds, and according to Dr. Darwin, one of the Matlock springs issued from cracks in the upper surface of a bed of toadstone.

Many of the springs are warm, or at least tepid. The most noted are at Buxton, Matlock, and Bakewell. Those at Buxton are supposed to have been used by the Romans. The temperature of St. Ann's Well is 81 deg. F. The water has been frequently analysed, and is remarkable for the amount of free nitrogen dissolved in it. It was found to deposit a hydrated peroxide of manganese on the walls of the bath. Another spring supplies the tepid swimming bath.

The temperature of the warm springs at Matlock Bath is 68 deg. F. They supply the Fountain swimming bath, and smaller baths at the New Bath and Royal Hotels. An analysis of the spring at the Fountain baths was made by Dr. Dupré. It contains

	Grains per gallon.
Chloride of Sodium	4·57
Sulphate of Magnesium	9·73
Sulphate of Calcium	2·04
Carbonate of Calcium	14·68
Silica	0·71
Total	31·73
Organic matter, traces of alumina, minute traces of potassium, lithium and strontium and loss... ...	1·03
Total dry residue	32·76

and a small quantity of free carbonic acid.

The old swimming bath at Bakewell is supplied by a spring at a temperature of about 60 deg.

Igneous Rocks.

The igneous rocks of Derbyshire are locally known as Toadstones. The word is derived either from the supposed resemblance of the amygdaloidal varieties to the back of a toad or it is a corruption of the German Todstein (Deadstone), so called because the rock was considered to be unproductive of ore. It is also known as dunstone, channel, blackstone, and cat dirt. The latter name is applied to the soft decomposed green variety, but the remaining terms appear to be used more or less indiscriminately by the miners. "Toadstone, or Channel," was the name used in Whitehurst's time (1778) for the ophitic dolerite at Black Hiliock. In the Wakebridge mine, near Crich, the dark coloured rock, often amygdaloidal, was called Blackstone, and the softer and more decomposed parts were called Toadstone.

Pilkington apparently used Blackstone as a general word for the igneous rocks of the county. He applies it to the lava-flow near Snitterton, to a lava or a sill lower in the series, and also to the agglomerate, or else to the bedded tuff near Grange Mill. We have already referred to the circumstance that the old geologists considered that there were three beds of toadstone continuous throughout the limestone which divided it into four parts, and that they also recognised "chance" beds of toadstone which were only local.

Some years ago the officers of the Geological Survey showed that this opinion would no longer explain the facts of the case. The geological maps of the county were made on the one-inch scale before the microscope became an adjunct to field-work, and when comparatively little was known about the igneous rocks. The toadstones were mapped on the assumption that they were contemporaneous with the limestone, and in some cases it was found necessary to introduce faults which are no longer required when the intrusive nature of the rock is recognised.

It was not until 1894 that the belief in the contemporaneity of the toadstone was shaken. In that year the author had the pleasure of accompanying Sir A. Geikie over the district. As a result of his visit, an interesting section on the Toadstones of Derbyshire appeared in his book on "The Ancient Volcanoes of Great Britain," to which the reader is referred. Sir A. Geikie pointed out that the toadstones include volcanic vents or necks—the remains of the pipes through which the materials found their way to the surface—and intercalations of tuff and lava, and at least one intrusive sheet or sill. Previously to 1894, the author had only studied the petrography of the toadstones, but since then has mapped the greater portion of the igneous rocks on the six-inch scale, and microscopical examination of many more specimens has been made hand in hand with field-work. Though much remains to be done before we can arrive at the history of the Derbyshire volcanoes, we shall endeavour to indicate briefly some of the interesting results which, up to the present, have been arrived at, reserving doubtful points for future investigation.

Some of the outcrops of toadstone marked on the one-inch map as contemporaneous lava-flows lose their simplicity and become more complicated when examined in detail. One of them proves to be two necks of agglomerate with an associated bed of tuff higher in the series, another consists of several lava-flows and a sill, and a third comprises a lava-flow, bedded tuff, agglomerate probably marking vents, and a sill. Several outcrops are found to be more extensive than was supposed, and exposures which are not marked on the geological maps continue to be found at intervals. For a long time we have had proof that volcanic action took place at intervals during the deposition of the last 1,500 ft. of the Mountain Limestone, but the finding

of bands of ash intercalated with some 100 ft. of the lower Yoredale rocks has carried the history of the volcanic action in the county a stage further.

The igneous rocks may be divided into two classes, which are generally easy to distinguish in a hand specimen, viz., massive and fragmental. Some of the massive rocks include lavas which are interbedded with the limestone and have a vesicular and sometimes slaggy structure. Others consist of a coarsely crystalline dolerite or a fine grained basalt, cutting across the beds of limestone, and are either sills, vents, or dykes. The fragmental rocks are interbedded tuffs contemporaneous with the limestone, or are vents which cut across the limestone beds. In some cases so small a quantity of the rock is exposed that its relations to the surrounding limestone have not been determined. It is probable that the igneous rocks of the county eventually will be classified into more than a dozen vents, one of basalt and the rest of agglomerate, with a few small dykes, about half a dozen sills or intrusive masses, five or more deposits of bedded tuff, numerous lava-flows and thinner intercalations of tuff. We will describe first several of the vents, tuffs without lavas, lava-flows, and intrusive sills in the Mountain Limestone, and then conclude with the igneous rocks of the Yoredale series.

Volcanic Vents.

Hopton Vent.—At the village of Hopton, about two miles south-west from Wirksworth, and close to the boundary between the Mountain Limestone and the Yoredale shales, is the most southerly vent in the main inlier. Like many of the Derbyshire vents, it is not separated by any difference in contour from the surrounding limestones and forms no feature in the landscape. But from the nature of the agglomerate of which it is composed, and the manner in which it cuts across the upper beds of the Mountain Limestone, there is no doubt of its origin. It is elliptical in area. The major axis is about $\frac{1}{3}$ mile in length, and lies in a north-west and south-east direction. The minor axis is about $\frac{1}{8}$ mile in length. A short distance to the east of the agglomerate the limestones are seen dipping 10 to 20 deg. south-east, which is in the same direction as the longer axis of the ellipse. Immediately north of the igneous mass, the dolomitized limestones dip south-east also, but as the hill towards Via Gellia is ascended the dip decreases, and near the High Peak Railway the beds are horizontal. The toadstone was mapped by the Geological Survey as interbedded with the limestone, and was supposed to be some 1,800 ft. down in the series and below the toadstone seen in the cutting of the High Peak Railway. Two curved faults were introduced to separate the agglomerate from the Yoredale rocks on the south. There seems, however, to be

no reason for the faults now the intrusive nature of the rock is ascertained. About half a mile south-east of the vent, and on the opposite side of the valley along which the Wirksworth road runs, is the Kirk Ireton outlier of Shale Grit. In Stainsbro Quarry the grit is seen to dip 15 deg. south-east, or in the same direction and almost at the same angle as the Mountain Limestone near Hopton. If some springs lower down the hill than the quarry be taken as the base of the Shale Grit, there is about 700 ft. for the Yoredale beds to come in between the Mountain Limestone and the Shale Grit. Half a mile south-west of the vent the shales are seen to be nearly horizontal. Very good sections of the agglomerate occur along the Wirksworth and Carsington road, and also on the side of the road which has been cut in the bank of the ravine leading down from Via Gellia on the north. The rock consists of a coarse tumultuous agglomerate composed of numerous small lapilli, with many more or less angular blocks of dolerite and basalt. The agglomerate is pierced by at least three veins or small dykes of a black fine-grained rock, enclosing reddish fragments, which contain felspars and are probably small pieces of the agglomerate caught up by the dyke. Plate IV, Fig. 2, is from a photograph of the agglomerate on the Hopton and Wirksworth road.

No bedded tuff has yet been found in connection with the vent. Any such deposit, if present, would probably be in the Yoredale shales, of which no good section is seen in the immediate neighbourhood.

The Speedwell Vent, about a quarter of a mile S.E. of the entrance to the Speedwell mine, near Castleton, and between the 800 and 900 ft. contour lines, is a small vent, elliptical in outline. It pierces the limestones near the base of the northern slope of Cow Low, and is the most northerly vent in the county. The limestones may be seen dipping about 20 deg. N., on the north, south, and west of the agglomerate, and within a short distance of it, so that the igneous rock undoubtedly cuts across the beds, which, from their position, are very near the top of the Mountain Limestone. The agglomerate is not well exposed, but a portion of it forms a low ridge covered with grass and about 80 ft. in length. It is composed of a mass of small lapilli containing crystals and seldom vesicular. Scattered through this softer and more decomposed rock are blocks of a doleritic type, with minute felspars and an isotropic ground-mass.

Grange Mill Vents.—The most interesting group of vents is found at Grange Mill, about five miles west of Matlock Bath. Unlike the majority of the Derbyshire vents, they form two hills, which present a marked contrast to the scenery of the surrounding limestone. Two dome-shaped hills, with grassy slopes and well-marked contours, rise from the valley to a height of 100 and 200 ft. respectively. Their summits are more than 900 ft. above

the sea. The larger vent covers an area measuring 2,400 by 1,300 ft., and the smaller one an area of 1,300 by 900 ft. Good views of these hills are seen on the roads from the village of Aldwark and from Longcliffe Wharf to Grange Mill. The smooth and steep grassy slopes consist almost entirely of a grey rock with green lapilli and a few limestone pebbles. It weathers into spheroids, some of which are well exposed opposite a cottage in the southern vent close to Grange Mill, on the road to Winster. On the hillsides are found a few blocks of saccharoidal limestone, some of which are several feet in length.

The rocks in the immediate neighbourhood of the vents form

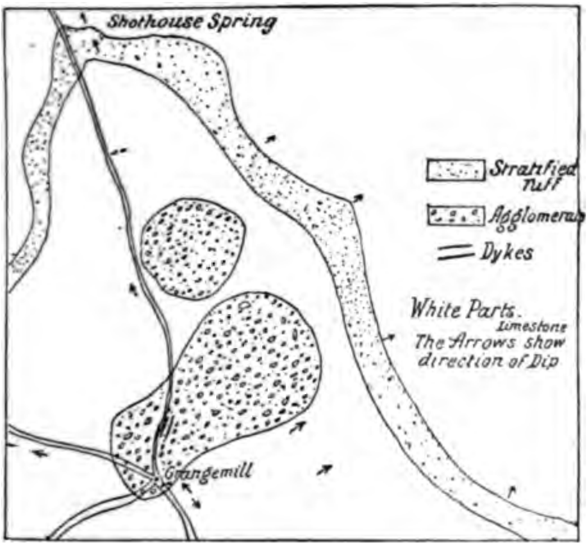


FIG. 4.—PLAN OF NECKS AND BEDDED TUFF AT GRANGE MILL, FIVE MILES WEST OF MATLOCK BATH.—*Sir A. Geikie.*

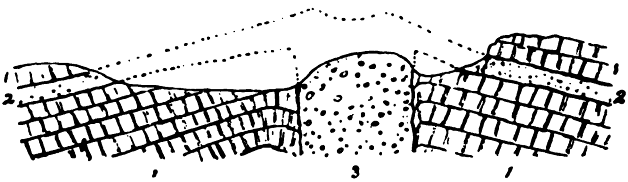
the northern part of a dome, the longer axis of which ranges N.N.W. The two vents lie on this anticline. In several places the limestone is seen within a few feet of the agglomerate. S.W. of the northern and smaller vent, it dips N. or N.W. at an angle of 10 to 15 deg. South of the southern vent, the beds are much disturbed, and at one point their upturned edges may be seen striking at the agglomerate. There is, therefore, no doubt that the igneous rock traverses the limestone beds.

East of the vents is a small valley with its eastern slopes running up to a well-marked escarpment of limestone higher in the series. This escarpment reaches a height of 1,000 ft. above the sea, and may be traced from near Whitelow Farm, where the

beds dip south-east and east, to Shothouse Spring, where they dip nearly north.

West of the vents is a smaller and less marked escarpment of limestone, which may be traced, with the exception of a few breaks, from near Aldwark Grange road to Shothouse Spring, where it joins the eastern escarpment. A bed of laminated tuff underlies the escarpments on both sides of the valley. It is about 90 ft. thick and made up of alternations of finely and coarsely laminated bands of lapilli in a calcite cement. It is exposed at Shothouse Spring and near Whitelow Farm on the east, being continuous between these two places, as indicated by fragments in the grassy slope. It can also be traced on the western side of the valley from Shothouse Spring to within a short distance of the Aldwark Grange road.

The limestone resting on the ash is nodular and concretionary



(Figs. 4 and 5 reprinted, by permission, from "The Ancient Volcanoes of Britain.")

FIG. 5.—SECTION ACROSS THE SMALLER VOLCANIC NECK AND THE STRATIFIED TUFF IN CARBONIFEROUS LIMESTONE, GRANGE MILL.—*Sir A. Geikie.*

1. Limestone 2. Stratified tuff intercalated among the Limestones
3. Agglomerates

in character, and similar to that found above the tuff bed at Litton, near Tideswell. Though no thin bands or intercalations of tuff have been found in the escarpments, recent examination has led to the discovery of numerous minute lapilli, distributed irregularly through the limestone up to a height of at least 18 ft. above the ash at Shothouse Spring. The clay bed in the adjacent quarry, which contains nodular pieces of limestone with lapilli in them, may possibly be the decomposed portion of an ash or ashy limestone. The general arrangement of the rocks is shown in Fig. 4, and a section through the smaller vent from east to west in Fig. 5, which are from blocks lent by Sir A. Geikie. The tuff has since been traced farther to the south-west, and beyond the boundary of the plan (Fig. 4), and the southern vent a short distance farther to the north-west. Two small dykes of dolerite traverse the southern vent, and are only seen for a short distance. The northern one is at least several feet in width. The southern, which is much smaller, penetrates the agglomerate to a height of several feet near the roadside, and either dies out or changes its direction and turns inwards into the hill.

Ember Lane Vent.—Immediately east of Bonsall, and about two miles north-west of Cromford, a coarse agglomerate is exposed in the banks of Ember Lane and in the field above. It extends over 1,000 ft. in a north-west direction, and at its broadest part measures nearly 400 ft. It is remarkable for the large admixture of calcareous material with the volcanic detritus. The rock may be described as a calcareo-igneous breccia, and consists of an intimate mixture, in varying proportions, of limestone fragments containing fossils—some angular and others more or less rounded, and of volcanic lapilli, which are often of a dirty green colour. A short distance higher up the lane it consists of a more comminuted volcanic detritus containing a few limestone pebbles as large as one's fist firmly embedded in it. The position and extent of this agglomerate and its relations to the surrounding rocks, as far as they have at present been ascertained, are indicated on the accompanying map, Plate III. Unfortunately there are no exposures showing the dip of the beds of limestone contiguous to it. The only rocks seen near it consist of quartz or silicified limestone, from which all trace of bedding has been obliterated. The composition and appearance of the agglomerate, and the fact that it cuts across the strike of the unaltered limestones 500 ft. north of it, seem sufficient to justify us in considering it to be a vent.

On the south-east it abuts against a much decomposed vesicular toadstone, which apparently belongs to the same lava-flow as that which forms the summit of Masson Low, and on the north-west there are traces of a similar rock. Two other and smaller patches of agglomerate, one a short distance north-east of Low Farm, the other north-east of Bonsall, probably mark two smaller vents.

Kniveton Vents.—Several exposures of igneous rock are found in the inlier of Mountain Limestone, near Kniveton. Near the western boundary occur three or four patches of agglomerate which probably mark the position of vents. The largest of these traverses the upper beds of the Mountain Limestone and perhaps also the lower beds of the Yoredale shales. It covers an area of about 700 or 800 ft. by 400 ft., is cut by two streams and forms the ridge of a hill between them. The beds surrounding it are very much contorted. On the north and south the limestones dip east and west at high angles, forming an anticline through which the agglomerate has made its way, and on the west the beds are vertical with a N.N.W. strike. The agglomerate consists of more or less rounded blocks of a vesicular dolerite and pieces of limestone mingled with a finer deposit of lapilli. Half a mile north, and near Lea Hall, is another small mass of agglomerate, of which only a few feet are exposed. Its boundaries have therefore not been defined, and sufficient evidence has not been obtained to say whether it is a vent or a

bedded tuff. Another small patch of agglomerate is found south, east of the large mass, and probably marks the site of a vent-since it apparently cuts across the strike of the limestones a short distance from it. The fact that the country is covered by a drift renders it difficult to trace exactly the boundaries of some of these patches of igneous rock.

TUFFS WITHOUT LAVAS.

Some of the toadstones interbedded with the limestone consist of bands of tuff unaccompanied by lava-flows. There are at least five of them. The thickest is at Ashover, in the small inlier of Mountain Limestone. A shaft was sunk in it to a depth of 210 ft., but the bottom was not reached. It is seen in two cuttings which have been made to the limekilns on the east side of the road between Milltown and Ashover and dips beneath the limestone. For some feet below the junction it is much decomposed. It is laminated, contains fragments of chert, of limestone, often rounded, and of amygdaloidal dolerite, and is traversed by veins of calcite. The matrix is composed of lapilli, cemented with volcanic dust and calcite.

At the village of Litton, near Tideswell, is a well-banded tuff intercalated with the limestone. It may be traced from near Tideswell Lane Head on the N.W. under the limestone escarpment of Litton Edge, which dips about 10 deg. N.E. to the Peep o' Day, the highest house in Litton. It is exposed in the fields north of the village, and at the place where it crosses the road. The author has not yet been successful in following it from this point down into Cressbrook Dale, though it is mapped by the Geological Survey as continuous with a similar deposit on the eastern side of the Dale. Its greatest thickness is about 150 to 200 ft., and it appears to thin out to the N.W. and in Cressbrook Dale. It consists of alternations of fine and coarse laminæ of a green and yellow colour, with pebbles of coralline limestone and blocks of dolerite or basalt up to 18 inches in length. The matrix is formed of very vesicular lapilli cemented by calcite. In Cressbrook Dale some portions are very fine grained, and slabs are found about a foot in length which can readily be split into thin laminæ. Below this tuff, and separated from it by 15 to 20 ft. of limestone, is a lava-flow 10 to 20 ft. thick seen in Cressbrook Dale. The limestones above the Litton tuff contain a few lapilli up to a height of at least 18 or 20 ft. The bedded tuff at Shothouse spring has already been described.

A short distance N.W. of Tideswell a bedded tuff is exposed for a distance of 50 ft. Its thickness is unknown, as the base is not visible. It consists of laminæ, but the component fragments are not so small as those in the finely-banded tuffs. It is hard,

and consists of vesicular lapilli varying in size from an inch in diameter downwards, and contains blocks of dolerite.

The fifth tuff bed occurs in the Yoredale shales at Tissington, probably only a short distance above the main mass of Mountain Limestone. A description of it will be found under the igneous rocks of the Yoredale series.

Near Sparrow Pit last winter the author found blocks of a granular limestone containing numerous volcanic lapilli with felspars in them. They were not in situ, but had evidently been obtained in making a trench or watercourse, and are probably from the upper beds of the Mountain Limestone or the base of the Yoredales. They are interesting, because they give indication of a mingling of volcanic detritus with the limestones in the northern part of the area.

LAVAS.

The lava-flows took place on different horizons, and were of limited horizontal extent. The volcanoes from which the tuffs and lavas were ejected were small and of the puy type, and the lava streams and deposits of tuff did not extend to a great distance from the vents.

Evidence of the thinning out of the lava-flows and of their limited range may be obtained not only from records of mining, but also by an examination of their occurrence in the field. The following variations of the thickness of the toadstone, which is an amygdaloidal lava, in the interior of Crich Hill were noticed by Mr. Alsop during mining operations. "A bed of clay one foot thick becomes within a short distance fourteen feet thick, and contains large nodules of compact toadstone, whilst the thick bed of toadstone actually sunk through at one shaft diminishes to a thin bed at the other mine. The beds were traced continuously from mine to mine." In two mines on the west side of the hill the toadstone was reached at 80 and 75 fathoms, and its thickness was found to be 11 fathoms and 20 fathoms respectively.

In the section along the Midland Railway the Geological Survey officers found that two beds of limestone in contact at Cressbrook and Litton Tunnels were separated at Litton Mills by a mass of toadstone which finally attained a thickness of 100 ft. There was no sign of alteration in the underlying limestones at their junction with the toadstone. The discovery of tufaceous limestone and bedded tuff at the base of this toadstone supports the opinion that the rock represents a lava-flow and not an intrusive sill. There is also evidence that this bed thins out in the opposite direction at Great Low on the Ashbourne and Buxton turnpike road. The upper bed of toadstone in the Matlock district appears to thin out a short distance east of Ingbole Wood. It is

probable that the largest of the lava-flows did not extend to a greater distance than five miles. That which forms the second toadstone of the Matlock District can be traced for a distance of four if not five miles, and the largest in the Miller's Dale District once covered an area of at least 4½ by 2 miles in extent.

The beds generally vary in thickness from 100 ft. downwards. But the two largest lava streams probably attain a greater thickness than 100 ft. Near the top of Cressbrook Dale a small flow 10 to 20 ft. thick is seen. Immediately south of the fault which bounds the southern portion of the Tideswell Dale inlier are two small lava-flows 15 to 20 ft. thick, and separated by about 15 ft. of limestone. There are indications that some of the beds are made up of a succession of lava-flows. The toadstone at Litton Mills was considered by the Geological Survey to be composed of at least five thin beds, which may represent different outpourings of lava.

The contemporaneous lavas consist of a dolerite, black or dark green when fresh, but grey, brown, chocolate, or light green when weathered. The upper and lower portions of a bed are vesicular and the central parts are often harder and free from vesicles. The vesicles are irregular in shape and size and are frequently filled with calcite and other alteration-products, the exact nature of which has not been determined. In a few cases the amygdules consist of jasper or of chalcedony. The rock is often traversed by veins of calcite and in some cases contains small nodules and veins of quartz and of jasper. The so-called "Buxton Diamonds," small quartz crystals, are found in geodes or cavities in the toadstone. The limestone underlying the toadstone often presents a very uneven surface. Numerous holes, several feet in diameter and in depth, occur in it, in such a manner that in a section seen in a vertical cliff the upper boundary of the limestone is a series of irregular crests and hollows. A similar contour is seen in the surface of the limestone below the bed of shale and the wayboards of clay at Crich and other localities. These hollows are probably due "to carbonated water circulating along the junction of the beds long after the formation of both limestone and toadstone." When very much decomposed the toadstone weathers into a greenish or yellowish clay and sometimes retains traces of its origin in the green amygdaloids which can be picked out of the softer portions of the mass.

We will now give a brief description of a few of the lavas. At the bottom of the valley of Miller's Dale a small dome in the limestone brings to view the upper part of a lava-flow which is about 150 ft. lower in the series than that seen in the railway cutting above. It appears soon after leaving the last house in Miller's Dale and can be traced under the limestone escarpment as far as Ravenstor, where it disappears under the limestone with a S.E.

FIG. 1.—INTRUSIVE DOLRRITE ABOVE LIMESTONE, TIDESWELL DALE.
d = dolerite. *l = limestone (marmorised.)*

FIG. 2.—LAVA AND TUFACEOUS LIMESTONE RESTING ON LIMESTONE.
BUXTON LIME FIRMS CO.'S QUARRY, NORTH OF MILLER'S DALE STATION.
t = lava. *a = tufaceous limestone.* *l = limestone.*
(From Photographs by H. Arnold-Bemrose.)

dip. It is very much decomposed, vesicular, and amygdaloidal, and is fairly typical of the lavas of the district. The junction of its upper surface with the limestone is visible. Under Ravenstor the junction has been removed by water flowing along the top of the impervious rock. This has resulted in a small cave, the floor of which is toadstone and the roof limestone. The latter rock contains cubes of pyrites and the upper surface of the toadstone is soft and contains numerous small crystals of selenite, probably due to the decomposition of the pyrites. The upper decomposed portions of lavas in other parts of the district often contain pyrites, and this mineral is especially characteristic of the agglomerate at Kniveton and the bedded tuffs at Tissington.

A lava-flow may be preceded or followed by a fall of volcanic tuff. An interesting example of the former occurs near Miller's Dale, and of the latter a short distance from Matlock Bath. The lava, which may be traced from Litton Mills to Great Low, is exposed along the railway cutting, and is probably the same bed as that which occurs on the west slope of Hammerton Hill, forms a ring round Crichley Hill, with a cap of limestone on the summit, and also composes the hill called Knott or Knock Low, a prominent ridge N.W. of Miller's Dale Station.

East of the station, in a tram line cutting belonging to the Buxton Lime Firms Co., Ltd., the junction of the limestone and the toadstone above it is well exposed. Two feet of clay rests on the limestone, above this are 2 ft. of a platy and fine-grained, crystalline, tufaceous limestone with few organisms. This is followed by an amygdaloidal dolerite about 9 ft. thick, which probably represents a small lava-flow. It is succeeded by a well-bedded and coarse-grained tuff at least several feet in thickness, and this in turn by the lava-flow, which extends for a distance of several miles. The coarse-grained tuff is seen several hundred yards to the west, near the footpath to Priestcliffe, and the tufaceous limestone appears resting on the top of the limestone in a quarry several hundred yards to the east. Traces of a coarser and harder tuff are also found further east. The junction of this bed of lava and the limestone is at present well exposed in the quarry at the foot of Knott Low on the opposite side of the Dale and immediately north of the station. On the limestone rests several feet of a decomposed calcareous tuff or tufaceous limestone similar to that near the tram line. It is succeeded by the vesicular dolerite which forms a greater part of the Low. The white limestone, light brown tufaceous limestone, and dark-coloured toadstone, are easily distinguished at a distance Plate V, Fig. 2. This hill is a short ridge rising steeply from the surrounding country. Its isolated position and contour suggest a volcanic vent; but closer examination proves it to be one of the few cases, if not the only case in the district, in which part of a lava-flow forms a prominent hill. On the north, west, and south-west, and in the quarry on

the south, the limestones are seen to dip regularly beneath the toadstone, which in some parts of the hill weathers into spheroids.

The lava which forms the summit of Masson Hill, and which may be traced for several miles, was succeeded by a fall of volcanic tuff. The bedded tuff is best seen near Tearsall Farm, and may be traced for at least a mile along the upper surface of the lava in a westerly direction. Near the farm the finely laminated tuff of a buff colour and similar to that at Litton is seen dipping under the limestone and resting on the vesicular toadstone. It is about 20 ft. thick.

THE SILLS.

Several of the toadstones occurring in the Mountain Limestone are undoubtedly intrusive sheets or sills. They differ from the lava in several respects. They weather less rapidly and consist of a hard coarsely crystalline dolerite or a basalt, and are non-vesicular. In some cases they have altered the rocks in contact with them, and cut across the beds of limestone. But in no case has the author found any alteration in the limestones due to a true lava-flow. Unfortunately all these characteristics are not always present, or they are not to be found owing to the very small exposure of rock seen or to the removal of a very great portion of it by denudation. Sometimes the toadstone transgresses the beds of limestone, and the latter are not altered, at others the limestone, above or below the igneous rock, has been marmorised, but the dolerite is not seen to cut across the beds owing to so small a portion of it being exposed. The structure of the rock appears to the author to be a less decisive test of intrusiveness than its behaviour with regard to the surrounding limestones. Each case should be decided on its merits, and it would be unsafe to decide on the intrusive nature of a rock by its structure alone, unsupported by field evidence.

Peak Forest Sill.—In Dam Dale, south of the village of Peak Forest, is an intrusive sill of ophitic dolerite. Its base is not seen, and its thickness is unknown. The portion exposed in this small valley does not cut across the beds, but its upper surface dips regularly beneath the limestones in a N.E. direction. The limestones immediately above it are marmorised for a distance of about 5 ft. A few feet higher up they contain chert nodules, and are partly dolomitised. The metamorphism may be traced about 800 ft. horizontally on the N.E. of the outcrop, and for about half that distance in the limestones on the N.W. on the opposite side of the valley, south of Damside Farm. The marmorised limestone is saccharoidal, and composed of crystalline

calcite, showing the characteristic twinnings under the microscope. Two yards above the junction the limestone contains traces of organisms and patches of either crystalline calcite or dolomite. The intrusive igneous rock is generally a coarse crystalline, ophitic olivine-dolerite, but near the junction it loses its ophitic structure and becomes more fine grained. It is free from vesicles or amygdaloids.

Pot Luck Sill.—One mile south-east of the Peak Forest sill a coarse ophitic dolerite is seen covering nearly [illegible] acres of the surface. It consists of northern and southern portions, irregular in shape and connected by a narrow band. Although the whole of the rocks associated with it have not yet been worked out in detail, sufficient evidence has been obtained to render it probable that it is a sill. About four hundred feet to the N.E. are a few large blocks of well marmorised limestone, and another [illegible] yards further in the same direction is a small limestone escarpment, in which the beds dip N.E. at an angle of [illegible] deg. The old shaft of the Black Hillock mine is on the S.E. margin of the northern part. The boundary then passes west to Rockend House and turns sharply south across the road and passes a short distance to the west of an old limestone quarry, in which the beds dip [illegible] deg. towards the S.W., and continues south until it reaches the smaller portion of the outcrop. The limestones are seen a short distance from the S.E. boundary to dip nearly south, so that the igneous mass cuts across the beds of limestone. A little further to the south it dips under them, but they are not marmorised.

On the N.W. the limestones dip S.E. at a small angle. The igneous mass apparently cuts across the limestone beds in two places on its S.E. boundary. In the old limekiln ground between the marmorised limestone and the escarpment to the N.E. were found blocks of agglomerate. In several places near the N.W. boundary the dolerite is very thin, and the limestone below it has been quarried to a small extent. It is seen resting on the limestone, and the latter is not marmorised. A few fields to the N.W. small blocks of similar rock are seen resting on the limestone. These probably represent small outliers of the thinner portion of the bed left by denudation. Other evidences of variation in the thickness of this bed are cited by Whitehurst, who gives a plan of the mines in the neighbourhood, showing that at Black Hillock, where the rock is at the surface, a shaft was sunk [illegible] fathoms without the bottom being reached (though Farey thinks the rock was sunk through), and that at other places, lying a short distance to the N.E., the igneous rock or "channel" varied from [illegible] to [illegible] fathoms in thickness. The rock is generally a coarse-grained dolerite, but towards the northern boundary it is finer in grain and loses its ophitic structure.

A vesicular dolerite may be traced in a north-west direction to

Oxlow Rake, but its relations to the sill have not been precisely determined. In the Black Hillock mine-heap the author found both types of the dolerite and a small piece of marmorised limestone. The Geological Survey officers were of opinion that the shaft was on one of the vents through which the toadstone came. They also mention that many fragments of limestone were found in the toadstone. These, and the pieces of agglomerate further north, lend weight to the view that the shaft was sunk in a vent, but the distribution and the varying thickness of the igneous rock rather favour the idea that it was sunk in the pipe through which the sill found its way before it spread between the beds of limestone. The limestones on which this sill rests at its western boundary are about 800 ft. higher in the series than those immediately above the Peak Forest sill. This estimate is arrived at by taking into account the dip of the beds and the fall of the ground between the two places.

Tideswell Dale Sill.—Another interesting sill occurs in Tideswell Dale, half a mile south of Tideswell village. The only visible portion is contained in a faulted inlier of Mountain Limestone. North of the inlier is a small lava-flow, and south of it are the two small lava-flows above referred to.

Intercalated with the limestones is a bed or stratum of red clay very much like a volcanic mud, which varies in thickness, and is sometimes absent in this part of the Dale. This appears to have been followed by a flow or several flows of lava. At a later period the intrusive rock made its way into the lava and spread along planes of weakness. It is found to occupy different horizons in the lava, sometimes resting on the limestone, at others on the clay, and at others on the vesicular lava. This coincidence of the sill with the lava is a remarkable one. The metamorphism extends some feet below the base of the sill.

Below the sill the clay has been indurated and rendered columnar to a depth of 9 ft., and the limestone has been altered to a hard saccharoidal marble to a greater distance from the junction than the alteration has extended in the limestones above the Peak Forest sill. That this metamorphism is due to the compact dolerite or sill, and not to the vesicular lava below it, is shown by the fact that the bases of the compact dolerite and the marmorised limestone are approximately parallel. Where the non-vesicular and compact dolerite rests on the clay or on the limestone the clay is rendered columnar, and the limestone is marmorised sometimes to a depth of 10 or 12 ft. Where some feet of the vesicular or slaggy toadstone separates the dolerite from the clay or the limestone beneath it the latter is unaltered. The sill is not found to transgress the upper portions of the vesicular lava, consequently it has not been sufficiently near to the limestones above the lava to alter them.

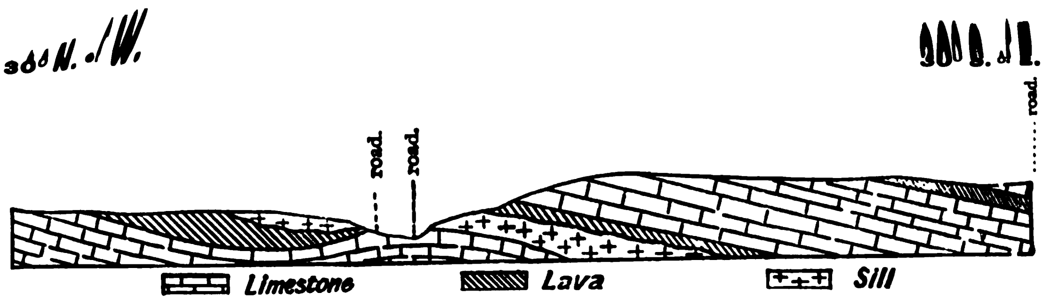
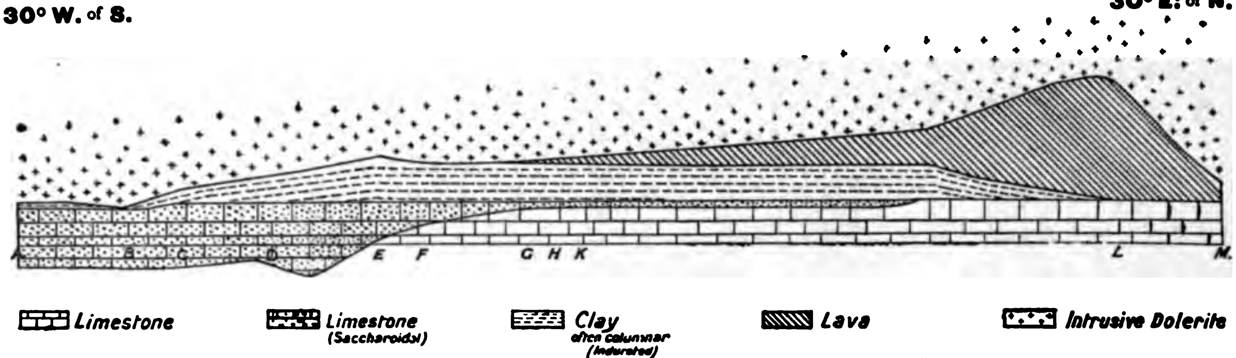


FIG. 6.—SECTION ACROSS TIDESWELL DALE.
Scale, 6 inches to 1 mile.



(Figs. 6 and 7 reprinted, by permission, from the Quart. Journ. Geol Society.)

FIG. 7.—DIAGRAMMATIC SECTION ALONG THE MIDDLE ROAD FROM MILLER'S DALE TO TIDESWELL, OPPOSITE THE OLD MARBLE QUARRY, ILLUSTRATING THE METAMORPHIC EFFECT OF THE INTRUSIVE DOLERITE.
Horizontal Scale, 96 feet ; Vertical Scale, 32 feet to an inch.

The datum-line AM is a thin bed of finely-laminated limestone. The boundary between the metamorphosed and the unaltered limestone is almost parallel to the lower surface of the intrusive rock.

The sill is about 70 ft. thick, and may be traced for nearly half a mile from north to south. It is well exposed in the old Marble quarry. It varies in structure, being coarsely crystalline in the centre and fine-grained near its upper and lower surfaces. The rock in the quarry is traversed by numerous veins of chrysotile or fibrous serpentine. The metamorphosed limestone is a hard crystalline marble, and at one time was largely quarried.

The Geol. Map, Pl. VI. and sections Figs. 6 and 7, and the reproduction from photograph, Pl. V. Fig. 1, will explain the position of the sill and its relation to the rocks of the neighbourhood.

Ible Sill.—A line drawn through the centres of the Grange vents ranges north-west, and if produced for a distance of half a mile in a south-east direction, passes through the centre of a mass of ophitic dolerite, close to the village of Ible. The igneous rock apparently disappears under the limestones on the north-east, which dip at an angle of 20 deg. in that direction, but it has not been ascertained whether it has made its way between the limestone beds. On the south it cuts across the strike of the limestones which dip west at an angle of 10 deg. The foot-path to Ible passes through a small ravine, cut by a stream in the igneous rock and the limestones to the south. The path, after passing through a small wood, crosses the junction of the rocks, and the limestones, within a few yards, are very crystalline. In front, to the north, the toadstone rises in a steep slope, and also forms a prominent ridge, trending north-east. The slope and ridge, which are now separated by the ravine, rise to a height of more then 200 ft. from the depression which marks part of the southern boundary of the igneous rock. There is no doubt that this igneous mass occupies different horizons in tne limestones by which it is surrounded.

It may be either an intrusive boss or the lower part of the pipe which supplied a sill higher up in the series. If the latter be the correct explanation, the whole or a greater portion of the sill and the limestones, amongst which it occurred, have been removed by denudation.

Masses of ophitic dolerite occur in other parts of the district, but sufficient work has not yet been done to warrant anything definite being said about them. We will content ourselves by simply mentioning one in the neighbourhood of Bonsall which covers a large surface of ground, and cuts across the beds of limestone lying to the west of it, and is probably a sill.

Igneous Rocks of the Yoredale Series.

The latest traces of volcanic activity in the district are found in the Yoredale shales and limestones. At Pethills, about half a mile south of the village of Kniveton, are two bands of

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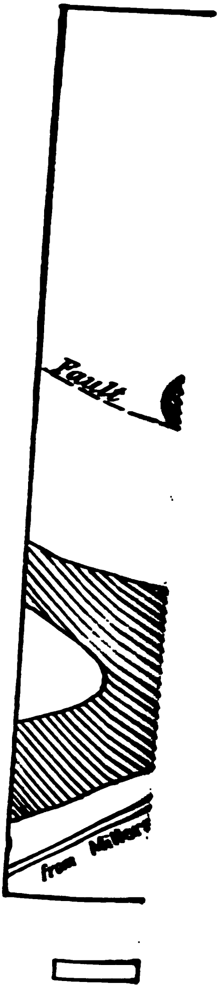

To face pag

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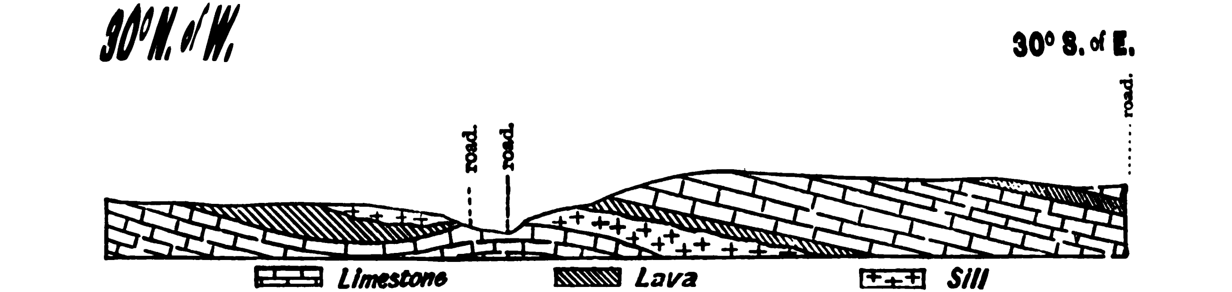

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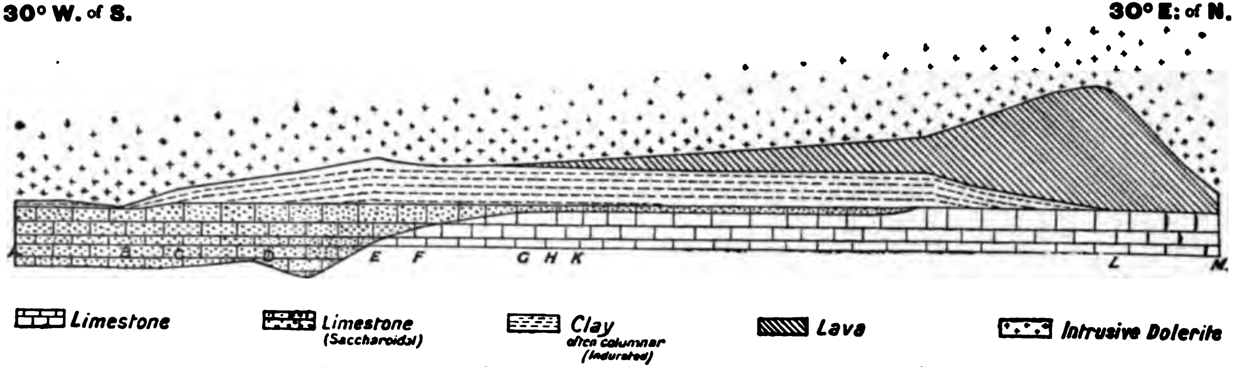

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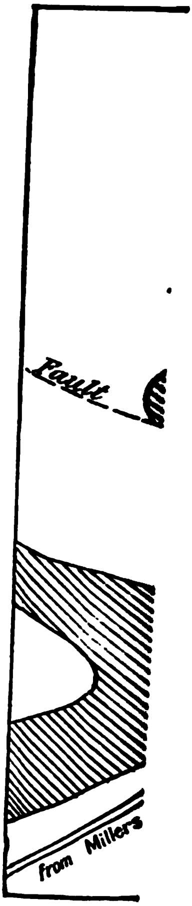
Fault
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amygdaloidal dolerite, which were considered to be either intrusive or brought up by two parallel faults. The junction of the igneous rocks with the limestone can be seen, and no evidence of faults or transgression of the beds of limestone and shale has been found by the author. In contact with the western band at its upper and lower surfaces the limestone is black and finely crystalline, and characteristic of many of the thin limestones. A few feet above the junction the limestones are dolomitised. The beds dip at a high angle, and the limestones and shales between the two igneous bands are nearly vertical, with a N.N.W. strike. It is possible that the beds form an anticline, and that the two bands of toadstone seen on either side of the axis belong to one and the same sheet. Whether these igneous rocks represent contemporaneous lava-flows or sills which have been intruded between the beds is uncertain, but we have now ample evidence of igneous action contemporaneous with the deposition of the Yoredale shales and limestones.

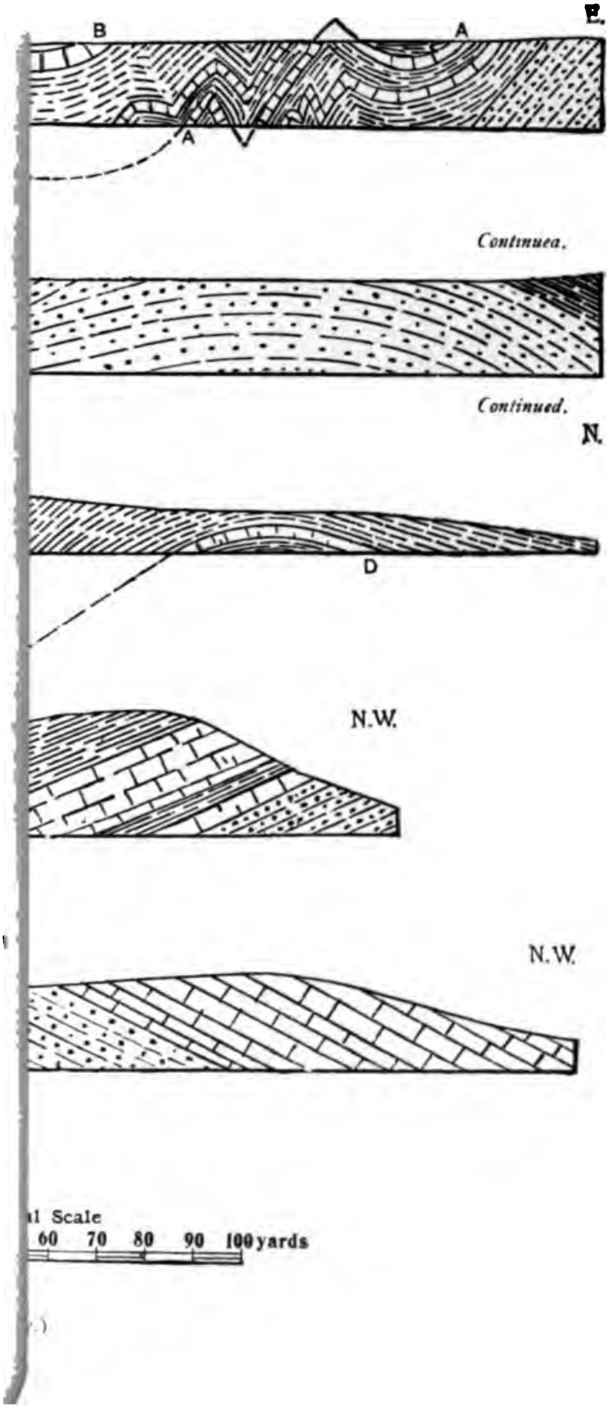
Near the village of Tissington a deposit of tuff covers a large extent of ground which is mapped as Yoredale Shales on the one-inch Geological Map. It is generally a bedded tuff, but on Wibben Hill is more like an agglomerate, the blocks of lava embedded in it being larger, more numerous, and closer together. The new L. and N.W. Railway passes through it. The folding of the strata has caused a repetition of the beds to be seen in the cuttings and has brought this tuff into view four times. At its second appearance near the middle of Tissington cutting the tuff-bed is exposed to view from top to bottom, and is about 140 ft. thick. It rests on cherty limestones, which probably belong to the upper beds of the Mountain Limestone. The tuff is generally course in texture, often has a distinct lamination, and contains numerous blocks of a dark blue or grey amygdaloidal rock, distributed irregularly throughout its mass. The finer portions of the tuff are made up of lapilli, varying from one inch in diameter down to a fine dust. They are very vesicular, contain no crystals, and are an altered glass or palagonite. The lower part of the bed consists of small "ball-like" lapilli, about one inch in diameter.

The ejected blocks found in the ash vary in size from several inches up to a foot in diameter, and are more or less rounded, vesicular and amygdaloidal. They are not so glassy as the lapilli, and unlike them contain felspar and olivine pseudo-morphs. In the thick tuff-bed there is an entire absence of non-volcanic material. After the prolonged eruption, or series of eruptions, which produced the thick band of tuff, there was a series of intermittent eruptions during the accumulation of at least 80 ft. of the shales and thin limestones. Volcanic detritus was mingled with the ordinary sediment of the sea bottom. Some of the limestone beds are free from tuff, whilst others contain varying

proportions of volcanic ejectamenta, and thus a limestone entirely free from volcanic sediment in one place passes into a tufaceous limestone or a shelly tuff in another on the same horizon. These intercalations of tuff, some of which in the shales are only $\frac{1}{4}$-in. thick, are seen in the railway cuttings above each of the four exposures of thick tuff, and also in Crakelow Quarry.

It is interesting to notice the variations in the shales and thin limestones above the tuff. Near the centre of Tissington Cutting, not far from Wibben Hill, there is a preponderance of shale. In Highway Close Barn cutting the limestones become more numerous and are closer together, whilst in Crakelow cutting there is little shale. Some of the limestones thin out very rapidly. In one place shale was deposited on the thick ash, and in another limestone and the volcanic fragments from the feebler eruptions which succeeded the great outburst fell in some places where shale and in others where limestone was being formed. This probably points to the shelving shore of a slightly submerged volcano which produced the showers of tuff. The position of the vent is a matter of speculation, and in the absence of further evidence it would be unwise to give any decided opinion. We may, however, mention a few indications of the probable direction in which the vent may be looked for, and they must be taken for what they are worth. We have already described several vents near Kniveton which are distant about half a mile from the nearest part of the ash, and about two miles from the farthest place to which it has been traced. The structure and composition of the lumps of lava found in these vents are exactly like those of the blocks found in the tuff, and it is quite possible that one of these vents may have supplied the tuff. In such a case we should expect to find the thick band of tuff in other localities and directions amongst the Yoredale rocks. But up to the present no traces of it have been found west, south, or east of the vents. It appears more likely, however, that the vent we are in search of is nearer the cuttings. Wibben Hill, close to the village of Tissington, has the contour of a vent. The deposit of tuff covers and surrounds it on all sides. North and south of the hill are small quarries in limestone, which is overlain by tuff. The shape of the hill and its position with regard to the surrounding tufaceous deposit, and the larger and more numerous ejected blocks on its slope, are in favour of its being a neck or the lower portion of a volcanic cone directly connected with the thick deposit of tuff. The only alternative supposition appears to be that it is a small sharp and very symmetrical pericline of limestone covered by a layer of tuff. It is probable, however, that in such a case the softer covering of tuff would have been removed by denudation, and have left the limestone exposed. The question for the present must remain unsettled.

Plate VII.



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PETROGRAPHY.

The Massive Igneous Rocks.

The microscopic structure of a few of the dolerites of Derbyshire was described by Mr. S. Allport and Mr. Teall. In 1894 the author described more fully the petrography of the dolerites and also that of the tuffs. The massive igneous rocks have three main types of structure, viz., olivine-dolerite with granular augite, ophitic olivine-dolerite and olivine-basalt.

The dolerite with granular augite consists of augite in small grains, olivine in idiomorphic crystals, plagioclase, giving lath-shaped or tabular sections and magnetite or ilmenite in rods or grains. A small quantity of interstitial material is sometimes present. This type is generally found in the lava-flows, but is not restricted to them. In the lavas the felspar crystals often attain a considerable size, but in some cases occur in bundles and plumes of microlites and in skeleton crystals. The rock immediately surrounding a vesicle will sometimes be composed of very small felspars in a base of iron-oxide. Though the minerals in a lava are often fresh, in the more decomposed portions of the rock they are entirely altered to serpentine, chlorite, calcite, oxide of iron, and other decomposition products. A rhombic pyroxene which often occurs in groups of crystals is found in some of the lavas.

The ophitic dolerite consists of augite in large ophitic plates forming the ground mass in which are imbedded the idiomorphic olivine, the plagioclase often giving large lath-shaped sections and magnetite or ilmenite. This type is found in the intrusive sills, and is also associated with the other two types, in outcrops whose relations to the surrounding limestones have not been yet ascertained. The whole of the minerals are frequently in an almost perfect state of preservation, the olivine, which is the first to undergo a change, often only containing small traces of serpentine along the cracks. The olivine is frequently replaced by a mica-like mineral, the exact chemical composition of which has not been determined. A qualitative analysis made for the author by Mr. Archbutt from a Pot Luck specimen showed that the oxides present besides silica were iron-oxide in comparatively large quantity, a fair amount of alumina, a small quantity of magnesia, and small quantities of soda and potash. This analysis differentiates it from iddingsite, which, according to Lawson, is non-aluminous and contains lime. Its optical properties agree with those of an almost uniaxial mineral. This pseudomorph occurs largely at Pot Luck, near Tideswell, at Peak Forest and other localities. A similar pseudomorph is also found at Peak Forest, having the same

optical properties and differing in colour and the small development of cleavage. The olivines in the Peak Forest sill are partly fresh and partly altered to this mineral, which is probably a first stage in the alteration to the Pot Luck pseudomorph. The ophitic plates of augite vary in size from 7·5 mm. in length, and from 5 mm. by 2·5 mm. downwards. They often show well-developed cleavage-cracks and polarize in brilliant colours; many of them are twinned.

The basalt contains olivine and large augite phenocrysts. The phenocrysts of olivine and augite lie in a ground mass of small felspar laths, of augite in small phenocrysts, grains and prisms, which give lath-shaped sections, and of magnetite or ilmenite. There is little interstitial matter present. The rock is a typical olivine-basalt, and in a very good state of preservation, all the minerals being quite fresh, except that the olivine is sometimes altered along the cracks. The olivine crystals have a well-marked outline, and often give the usual six-sided sections; they vary in size from 5 mm. down to ·06 mm. This mineral often occurs in groups of several individuals and may frequently be detected in a hand specimen by its green bottle-glass colour and fracture. The augite phenocrysts are of the usual form, often twinned, and attain a large size. Some of the largest are corroded, and others contain portions of the ground mass. The hour-glass and the zonal structure are frequent. The felspars belong to the labrador-anorthite group.

We will now note a few of the interesting cases of variation in structure of some of the intrusive rocks. The sill in Tideswell Dale is about 70 ft. thick, and may be divided into five bands or zones. The central portion consists of a band of coarsely crystalline ophitic olivine-dolerite, at least 6 ft. thick; above and below it are bands of the type with small grains of augite and large felspars. The lower of these bands attains a thickness of about 11 ft. Below it is a margin of fine-grained dolerite about 14 ft. thick. The uppermost band is composed of a similar rock. The fine-grained dolerite is in a very fresh condition. The felspars are small and often show signs of fluxion structure.

The upper margin of the Peak Forest sill also consists of a finer-grained rock than that lower down, though the conditions for examination are not so favourable as in the case of the Tideswell Dale rock, which is so well exposed in the quarry. The junction is concealed by grass. The following differences have, however, been ascertained. The mass of the rock is a coarse ophitic olivine-dolerite. In one specimen the augite plates are small and seldom contain or are penetrated by felspars; several prisms of augite are present. This mineral fills the spaces between the felspars, and the specimen forms a transition between the ophitic and the granular type. A specimen, one foot below the junction, consists of a much-altered dolerite, in which only altered plagioclase laths can be recognised. It is cut up into

separated patches by veins of a secondary silica, which forms a mosaic like that in the quartz rock of the Top Lift and other places. The patches of dolerite are also partly silicified and traversed by thin veins of quartz. Crystalline calcite is present. A specimen 9 in. below the limestone consists of a quartz mosaic with calcite and probably chlorite, but no dolerite. A specimen 7 in. below the junction is a much altered olivine-dolerite, consisting of altered and turbid felspars in laths and phenocrysts and phenocrysts of olivine, some of which attain a large size. The spaces between the felspars are probably filled by chlorite. A specimen 6 in. below the junction is similar to the preceding, and contains patches of calcite. The rock near the junction therefore appears to be an olivine-dolerite, which probably contained augite in grains, and is traversed by veins of silica. The Pot Luck sill consists of ophitic olivine-dolerite, which in some places passes into a sub-ophitic dolerite, and in others into one with granular augite.

The two small dykes which penetrate the agglomerate at Grange Mill show a slight variation in structure.

The coarser portions of the larger dyke consist of an olivine-dolerite with granular augite. The olivine is entirely altered, but the augite and felspar are fresh. The felspars are present in two generations. A second specimen differs from the first in having smaller felspars. This dolerite is very similar to the rock in the margins of the Tideswell Dale sill. The smaller dyke is more interesting. The lower and coarser portions are a much decomposed olivine-dolerite. The felspars are turbid and the olivine and augite grains altered to calcite. The felspars are as large as those in the coarser portion of the larger dyke. Higher up, the felspars become smaller, and the rock contains small patches which may be amygdaloids. A portion of the margin of the dyke, with the agglomerate adhering to it, consists of microlites and small laths of felspar in a brown and non-isotropic base. They extinguish parallel with their length and often have jagged ends. The majority of them are arranged parallel to the edge of the dyke: probably pseudomorphs of olivine are present. The agglomerate adhering to the dyke contains small brown vesicular lapilli which are free from crystals.

The Fragmental Igneous Rocks.

The fragmental rocks occur in vents and as bands of tuff ntercalated with the limestones. It is not always possible to tell from a hand specimen to which of the two classes a fragmental rock belongs. The only reliable evidence is that obtained by examining its mode of occurrence in the field. The interstratified tuffs are generally composed of laminæ varying in thickness and

in the coarseness of their component parts, and show frequent alternations of coarser and finer volcanic detritus. The material filling the vents often consists of a tumultuous mixture of large and small blocks of volcanic rock imbedded in a smaller detritus similar to that found in the bedded tuffs. Both classes of fragmental rock often contain blocks of dolerite or basalt and of limestone, and sometimes a large quantity of calcareous material. Lapilli play an important part in the composition of the whole of the fragmental rocks, whether in a vent or bedded tuff. They are generally minute fragments of a basic pumice, often crowded with vesicles, and rarely containing a few altered felspars or olivine crystals. In some cases they are isotropic, and the original glassy structure is well preserved, but often they are decomposed and are what has been termed palagonite.

They vary in magnitude from small fragments or shreds up to about the size of a marble. They have no counterpart amongst the lavas, *i.e.*, they differ from them in being more glassy, less crystalline, and contain more numerous and minute vesicles. In some cases the volcanic detritus consists of small fragments of a dolerite or basalt. The blocks of igneous rock included in the bedded tuffs and vents more nearly approach the lavas in structure, but differ from them in having a more glassy base and a greater number of vesicles, which are often very small.

Though no complete distinction has yet been made between the microscopic structure of the bedded tuffs and of the agglomerate filling the vents, a few of the differences between them may be mentioned. The bedded tuffs weather more rapidly than the material in the vents, though portions of the former may be obtained which are very hard. The lapilli in the tuffs are nearly always more glassy and less crystalline than those in the vents, and the rock more often consists of laminæ. There is one case, if there are not two, in which it is possible to compare the character of the agglomerate in vents with the tuffs which have been ejected from them.

The vents at Grange Mill are composed mainly of minute vesicular lapilli, very seldom containing crystals, and cemented together with a more comminuted volcanic detritus. No blocks of dolerite have been found in them, and the only traces of non-volcanic material are small rounded pieces of limestone, large angular blocks of the same rock, often marmorized, and a few pieces of quartz rock. The bedded tuff, of which only the upper portion is seen, consists of minute lapilli similar to those in the vent, but much more decomposed. No limestone fragments have been found in it.

The materials composing the vents and the bedded tuffs near Kniveton and Tissington are different in character from those of any other locality. All the igneous rocks in this neighbourhood contain a large quantity of pyrites. The Kniveton vents consist

mainly of more or less rounded blocks of a highly vesicular or amygdaloidal dolerite, the ground mass of which is more glassy than that of the lavas. The vesicles form a large proportion of the mass, and the small felspars are arranged parallel to the boundaries of the vesicles and pseudomorphs of olivine. The blocks are intimately mixed with, and their vesicles sometimes contain, small glassy lapilli with few traces of crystals; a few blocks of limestone are also found. The rocks of Wibben Hill are similar. The thick bedded ash at Tissington, which may have been ejected from Wibben Hill or one of the Kniveton vents, consists of glassy vesicular lapilli without crystals, and is entirely free from any non-volcanic detritus. The blocks contained in the tuff are like those in the vents, but, as might be expected, form a smaller proportion of the rock. The smaller intercalations of tuff are similar to the thick tuff bed, but contain very few and small ejected blocks, and are mixed with varying amounts of fossils and calcareous material.

The Hopton agglomerate differs from that in any other vent. It is a breccia, consisting of angular fragments of a glassy basalt cemented by small lapilli and calcite. The fragments are distinguished not only by their angular shape, but also by the very fresh condition of the augite and felspar contained in them. Felspar and augite fragments occur in the calcite-cement, and blocks of limestone are absent. In some parts the lapilli are silicified.

The agglomerate of Ember Lane is distinguished by the very large proportion of limestone fragments and calcareous material which are intimately mingled with the lapilli. The differences between these agglomerates are so well marked that it is possible to tell whether a hand specimen is from Kniveton, Grange, Hopton, or Ember Lane.

With the exception of the Speedwell vent, near Castleton, the fragmental material in the remaining tuffs and vents nearly approaches those of Grange Mill in structure. The lapilli in the Speedwell vent are seldom vesicular, often contain felspar and olivine pseudomorphs in a dense black or yellow matrix, very much like tachylite. More minute details of the microscopic structure of the fragmental rocks of the district will be found in the papers by the author, to which reference is made at the end of this Sketch.

MOUNTAIN LIMESTONE.

Very little work has been done in the microscopic examination of the finer-grained varieties of the Mountain Limestone of Derbyshire. Dr. Sorby examined a number of thin sections of Carboniferous Limestone from England and Scotland, but the greater portion of his specimens were from Derbyshire and the

neighbourhood of Bristol. His results, therefore, are in the main probably true for the rocks of this county. He found that "though there is a considerable variation in different specimens, yet on the whole there can be no doubt that by far the greater part of the identifiable fragments are joints of encrinites, often entire, but sometimes broken. Next in amount are fragments of brachiopoda, and then entire or broken foraminifera, which not infrequently are as important a constituent as they are in most specimens of chalk. The bulk of the recognisable fragments of corals and polyzoa is on the whole somewhat less but occasionally very great. Shell prisms are also present in considerable quantity."

The author has collected a number of thin sections, but up to the present has not been able to examine them in detail. The following brief notes, though they are only of the nature of an introduction to the subject, may be of interest. The specimens have been taken from different localities and horizons, but it is impossible to say how far they are typical of the whole of the limestones. A specimen from near Windy Knoll, given to the author by Dr. Wheelton Hind, appeared to be oolitic, but a thin section showed that it consisted of fragments of corals and other organisms, and small limestone pebbles containing a few quartz crystals. The structure was partly obliterated by alteration of some portion of the slide to crystalline calcite, and no oolitic grains were present.

The limestone above the bedded tuff near Grange, also above the tuff at Litton, and in many localities, weathers into small nodules. Examined with a lens, the rock is seen to be made up of small grains, which, however, are not oolitic, but are composed of fragments of brachiopoda, corals, encrinite stems, foraminifera, and other organisms, and also of irregularly shaped pieces of a previously consolidated limestone. These fragments of limestone frequently contain foraminifera, and other small fossils, and sometimes a few bipyramidal quartz crystals. The fossil and limestone fragments are often more or less rounded. This granular structure is, however, not confined to the nodular variety, but forms large portions of the massive beds of the Mountain Limestone. *Girvanella* has been found in one or two localities.

In the thin ashy limestones near the base of the Yoredales at Tissington were found worn shell fragments and small pieces of a previously consolidated limestone, sometimes containing a few quartz crystals. The limestone frequently contains well preserved foraminifera in such numbers that the rock is to a great extent composed of these organisms. Very few specimens of the limestone when examined microscopically have been found to contain grains with oolitic structure. The black or dark coloured fine-grained limestones, which are found in the lower Yoredales, and

in some of the upper beds of the Mountain Limestone, generally consist of a more or less crystalline calcite, with a black or brown material between the small grains. Sometimes a few traces of organisms are present.

Marmorized Limestone.

The limestone which has been completely marmorized is generally white, has a translucent surface when wet, breaks with a saccharoidal fracture, and is easily crushed into a white crystalline powder. It consists of crystalline grains of calcite, which give the usual cleavage lines and interference colours under the microscope. No crystalline silicates have been found in it.

Dolomitized Limestone.

Some of the beds in the Mountain Limestone are, as Dr. Sorby remarks, almost pure dolomite. He was able to prove, by selecting a specimen in which the alteration was incomplete, that the organic fragments had been changed into dolomite. At the same time he considered that "it is possible, and even probable, that a considerable part of the deposit originally contained a large amount of magnesia, since the dolomitic beds have a considerable horizontal extension, and are interstratified with rock of the usual type." A section cut from a specimen of dolomitic limestone from the Cumberland Cavern at Matlock was described by Mr. Rutley as consisting entirely of small rhombohedra of dolomite. His analysis "showed it to be almost identical in composition with the typical dolomites of the magnesian limestone series, the calcium carbonate amounting to 51·25, and the magnesium carbonate to 42·18 per cent., the remainder consisting mainly of silica with a little iron alumina and water." He found that after dissolving the rock in hydrochloric acid the residue consisted of "minute rhombohedra, some of which were considerably and others slightly eroded, whilst many exhibited perfectly sharp angles and edges. The thin sections examined by the author do not often show the forms of the rhombohedra so clearly. The grains are more irregular in shape and fit closely together. Some specimens are composed of very small grains of dolomite, whilst others have a very coarse crystalline structure. The dolomite grains sometimes contain patches of crystalline silica and quartz crystals, the largest of which seen measured 40 by 25 mm.

Silicified Limestone.

The silicified limestone or quartz rock is a granular rock with sometimes a black or dark brown material between the grains. Under crossed nicols it appears as an aggregate of quartz grains,

the majority of which are elongated in the direction of the least axis of depolarisation. They attain a length of 1·25 mm. They seldom have crystalline outline, but closely interlock and penetrate one another. A few of them are hexagonal in cross section. The rock often contains fluor in irregularly shaped masses and small cubes. The quartz in the quartzose limestone occurs in veins and small patches similar in structure to the quartz rock, and also in separate crystals with bipyramidal terminations.

The siliceous rock largely quarried at Bakewell consists of a micro-crystalline quartz mosaic, and often passes into a crypto-crystalline structure which contains small patches of the former. The threads of silica which traverse the rock are composed of a mosaic of clear quartz grains, which have no crystalline outline, and are not elongated.

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LONG EXCURSION TO DERBYSHIRE.

WEDNESDAY, AUGUST 2ND, TO THURSDAY, AUGUST 10TH, 1899.

Directors: H. ARNOLD BEMROSE, M.A., F.G.S., WHEELTON HIND, M.D., B.Sc. Lond., F.R.C.S., F.G.S., J. BARNES, F.G.S., G. E. COKE, F.G.S., AND PROF. CARR, M.A., F.L.S.

Excursion Secretary: FREDERICK MEESON.

(*Report by* H. ARNOLD BEMROSE AND WHEELTON HIND.)

THE object of the excursion was to study the Lower Carboniferous rocks of Derbyshire. The visit to the Mill Close Lead Mine, and the excursion to Nottingham were added to the usual seven days excursion. The number of members attending the excursions varied from fifty-two to sixty-nine. The headquarters of the party were at the Royal Hotel, Matlock Bath.

Wednesday, August 2nd. Directors: H. ARNOLD BEMROSE AND G. E. COKE.

In the afternoon a visit was made to the Mill Close Lead Mine. Through the kindness of Mr. Alsop, every facility was given for the descent of the party, which numbered thirty-eight. Six members went down the shaft which is being sunk in the Toadstone. A thin seam of coal in the Mountain Limestone was seen in the mine. The remaining members visited those portions of the mine which were in full work. They saw the junction of the limestone with the overlying shales, and the manner of occurrence, and the method of obtaining the ore, and on returning to the surface were shown the process of washing and separating it. The plans of the mine, and the very good collection of lead ore, calcite, fluor, and other minerals were examined with great interest. Afternoon tea was provided by the kindness of Mr. Alsop, and the party returned to Matlock by carriages.

Thursday, August 3rd. Director: WHEELTON HIND.

On alighting at Hayfield Station, the road lay over the upper beds of the Millstone Grit and the intervening shales, along the Kinder Stream towards Kinder Scout. Arrived at the S.W. flank of the hill, on a plateau formed by the fifth bed of grit known as Farey's Grit, the equivalent of the Pendleside Grit, the Director indicated the chief features of the landscape formed by beds of the Third, Fourth, and Fifth Grits and the intervening shales. The top of Kinder Scout consists of a plateau of some extent, formed by the almost horizontal beds of the Fourth Grit, covered by deep beds of peat; but the rocks appear weathered into fantastic shapes along the edges of the hill. Descending by Edale Cross, across the shales below the Fourth Grit, Farey's Grit and its shales were passed over in succession, and special attention was called to a bed of large "bullions" or concretions in the stream at Barber Booth, which the Director considered an important horizon, mapable throughout North Staffordshire, Cheshire, Derbyshire, South-east Lancashire, and South-west Yorkshire, containing a rich fauna which passed up into the Gannister Beds of the Coal Measures, but not passing down into the Carboniferous Limestone.

The Edale Valley was then crossed, the same beds being seen in stream sections on both sides, and an ascent made to Mam Nick, the entrenched camp on Mam Tor being noticed. At Windy Knoll, the cavern explored by Prof. Boyd Dawkins and others, which had yielded a rich mammalian fauna, was noticed, and the bed of elaterite and vein of fluor-spar in the quarry examined and collected from. Specimens of oolitic limestone, and limestone containing limestone pebbles, were examined from

the walls, though the bed was not seen *in situ*. Passing down the gorge of the Winnats, some of the party stayed to examine the Speedwell Mine; also a bed of rolled shell-fragments indicating a contemporaneous beach, or a bed subject to wave action, the horizon of which is at the top of the "Massif" of Limestone. A visit was paid to the Great Peak Cavern, and the stream of underground water passing through it was noted.

W. H.

Friday, August 4th. Directors: H. ARNOLD BEMROSE, WHEELTON HIND, AND J. BARNES.

The day's work began with the examination of the fossiliferous quarry at the bottom of Cavedale, the horizon of which is practically at the top of the Limestone. Two sections showing the rolled shell bed were visited, and another fossiliferous quarry on the same horizon at the mouth of the Odin Mine.

From this point a description of the physical features of the district was given, and then the shales containing *Posidoniella lævis*, *Aviculopecten papyraceus* and *Goniatites* were examined, and the section of Mam Tor noted. The contact of limestone and shales was seen in a stream, but the Director pointed out that the shales had probably slipped.

W. H.

At the foot of the Winnats, Mr. Arnold Bemrose drew attention to the agglomerate near Goose Hill Hall, and pointed out how the igneous rock cut across the beds of limestone, and the reasons for considering it to be a vent.

The Blue John mine was next visited, where The Ladies Walk, the Grand Crystallised Cavern, Lord Mulgrave's Dining-room, and other interesting features of the mine were kindly described by Mr. J. Barnes. (See p. 179.)

A detour to the village of Peak Forest was then made. Mr. Arnold Bemrose led the way to a small mass of intrusive dolerite which has been exposed by denudation in Dam Dale. The variation of the sill from a coarse ophitic dolerite to a fine-grained dolerite near the upper margin, and the very perfect marmorization of the overlying limestone, due to the contact of the igneous rock, were pointed out.

Barmoor Quarry was examined, with brecciated limestone and beds with fish teeth. Mr. Smith Woodward gave an interesting account of the fish from these beds, and *Psephodus* and *Psammodus* were obtained. Passing the Ebbing and Flowing Well, a halt was made in the cutting in the limestone along the tramway, where the actual sequence of limestone and shales is to be seen, the shale with "bullions" occurred higher up in the cutting of the Manchester and Buxton Railway.

W. H.

Saturday, August 5th. Director: H. ARNOLD BEMROSE.

The party proceeded to Miller's Dale by train. The route taken was down the valley of the Wye as far as Tongue End, and then up Tideswell Dale to Tideswell. The lava exposed in the bottom of the valley was examined and good junction specimens of the lava and overlying limestone were obtained at Rancher Tor. A considerable time was spent in Tideswell Dale in order to examine the faulted inlier of Mountain Limestone containing a sill intruded between lava-flows. Evidences for the faults and for considering the ophitic dolerite to be intrusive were pointed out in detail. Specimens of baked clay, marmorized limestone, of the igneous rock, and *Lithostrotion junceum*, *Lithostrotion irregulare* and *Dibunopyllum* were obtained. In the quarry, Mr. E. T. Newton gave a short address on the corals found in the Carboniferous Limestone. After lunch at Tideswell, the party walked to Litton to see the laminated tuff contemporaneous with the limestone. A very good coral bed was seen in the quarry near Peep-o'-day. A return to Miller's Dale was made by carriages; and (through the kindness of Mr. Brierly, Director of the Buxton Lime Firms Co., Ltd.) the section near the Station was examined. Tufaceous limestone with a small lava-flow, coarse bedded tuff and a larger lava-flow, were seen intercalated with the limestone.

Monday, August 7th. Director: H. ARNOLD BEMROSE.

The party drove to Cromford Station, and examined the shales with limestones. *Posidoniella* was found in the shales, and a gasteropod from one of the nodules of limestone. The quarry at Cromford in the upper cherty- and *Productus*-beds of the Mountain Limestone was visited, and *Productus giganteus*, *Productus hemisphæricus*, *Streptorhynchus crenistria*, a coral, and the tail of a *Phillipsia* were found. The Black Rocks composed of Kinder Scout Grit were next climbed, and a fine view of the surrounding country was seen. The party drove *viâ* Middleton and Ryder Point to Grange Mill. The bedded tuff at Shothouse Spring, and the vents of agglomerate near the Mill with two or three dykes were carefully examined, and the evidence of their origin discussed. The party proceeded down the Via Gellia examining the calcareous tufa quarry and walked up the hill through Bonsall to Pounder Lane. The members here examined the quartz rock, quartzose limestone, and agglomerate of Ember Lane, and returned over Masson Hill to the Hotel.

Tuesday, August 8th. Director: H. ARNOLD BEMROSE.

The party drove to Tissington, and on the way a halt was made at Hopton to see partially dolomitized limestone, and a neck of coarse volcanic agglomerate with several small dykes. On arriving at Tissington, the party walked along the New Rail-

way (by kind permission of the L. & N. W. Rly. Co.) and were accompanied by Mr. W. Hurst, the resident engineer. Sections in contorted and tufaceous Yoredale shales and limestones, and also the thick bed of tuff which in one place is exposed from top to bottom, were seen in the first cutting. Similar beds were seen in other cuttings as far as Crakelow, and in the latter cutting the thick tuff-bed was seen to be faulted against the Mountain Limestone. A climb to Crakelow Quarry was made, where nearly every bed of limestone is tufaceous. The rapid variation of the beds and intercalations of tuff were pointed out, and fossils were found in one bed of tuff. The party then walked to the Peveril Hotel, Thorpe, and after tea they returned to Matlock, *viâ* Longcliffe. The castellated weathering of the dolomitized limestone was remarked; and near Longcliffe Wharf Station on the High Peak Railway, at a height of 1,050 ft., a halt was made to visit an interesting sand and fire clay pit in a hollow in dolomitized limestone.

After dinner the hearty thanks of the Association were given to Mr. Bemrose, Dr. Wheelton Hind, Mr. Barnes and others, who had contributed so largely to the success of the excursion.

Wednesday, August 9th. Director: H. ARNOLD BEMROSE.

The party went by train to Ambergate and walked to Crich to see the faulted inlier and dome-shaped mass of Mountain Limestone. They were accompanied by Mr. Boag, the Manager of the Clay Cross Co.'s Works. The evidence for the three faults was fully explained. Some time was spent in the quarry in obtaining fossils, and several minerals. The bed of shale, some 220 ft. down in the Mountain Limestone, on which the landslip took place some years ago, was energetically examined for fossils. The Hill was climbed, the chasms due to the slip being passed on the way. From the summit of the Stand, or Tower, a fine view of the surrounding county was obtained. The descent to Wakebridge was made and the shales in the brook-course seen. The party then proceeded to Whatstandwell through quarries in the Millstone Grit. A pebble of foliated igneous rock found in the grit was obtained from a quarryman. It measured nearly 6 inches in length. The party returned to Matlock by train.

EXCURSION TO NOTTINGHAM.

Thursday, August 10th. Directors: G. E. COKE AND PROF. CARR.

(*Report by* F. MEESON.)

Thirty-five members left Matlock Bath for Nottingham. They then divided into two sections, one of which consisting of twenty-five members accompanied Mr. Coke, and through

the kindness of the Clifton Colliery Co., inspected the coal mine at Clifton Colliery, and then went on to Thurgarton. The other section accompanied Prof. Carr to the brickyard on the west side of Bulwell, where a section of the Middle Permian Marls, about 30 ft. thick, was seen resting upon the Lower Magnesian Limestone. The Permian Marls passed upwards without *apparent* break into the Lower Mottled Sandstone of the Trias. A quarry a little to the north of the brickyard was next visited, where the Lower Magnesian Limestone, about 30 ft. thick was seen. The party next drove to Kimberley to examine the section exposed in the excavation for the Great Northern Railway Station. This section shows at the top the Lower Magnesian Limestone resting upon the Marl Slate, at the base of which is a hard compact breccia about 3 ft. thick, composed of fragments principally of Carboniferous rocks in a calcareous matrix. This breccia forms the base of the Permian in Northamptonshire, and rests with a marked unconformity upon the upturned edges of the Middle Coal Measures.

After arrival at Thurgarton, both sections walked a short distance to the borehole which is being put down by Messrs. Barber, Walker & Co., as a trial for coal. The cores from the Trias and Permian formations were inspected by the party, and the boring machinery was explained by Mr. Coke. Mr. Shipman met the party and made a few remarks on the geology of the district.

The President thanked Messrs. Barber, Walker & Co., on behalf of those present, for the permission to visit the borehole; and Mr. Coke for the assistance he had rendered in organising the supplementary excursions.

EXCURSION TO WELDON, DENE, AND GRETTON.

SATURDAY, APRIL 29TH, 1899.

Director: BEEBY THOMPSON, F.C.S., F.G.S.

Excursion Secretary: BEDFORD MCNEILL, A.R.S.M., F.G.S.

(*Report by* THE DIRECTOR)

THE excursion was arranged in order to examine the whole of the strata comprising the Inferior Oolite in the area embraced. The sequence of beds will be best seen on reference to the accompanying diagram of comparative sections.

Weldon and Corby Brickworks was the first section visited. The clay worked here belongs to the upper part of the Upper Lias, and embraces a part of two zones, the Upper *Leda-ovum*-Beds (*Jurensis zone of Thompson*; *Lilli hemera of S.S. Buckman*), and the Middle *Leda-ovum*-Beds (a part of the *A. communis* zone). There is a false junction between the Upper Lias Clay and the Northampton Sand owing to the slipping of the

latter over the former; also, it was noted that the clay itself was thrown into a sharp fold, a result due, no doubt, to the slipping of the clay itself towards the valley.

Only a few fossils were obtained, but the visitors were shown the head of a *Teleosaurus* that had been found quite recently. A few years back a fairly complete skeleton of an *Ichthyosaurus*, 23 ft. in length, was found here, and is now in the Northampton Museum.

The Ironstone workings near the brickworks, and close to the village of Corby, were next examined, and attention was particularly directed to the Chalky Boulder Clay (A) with large erratics and scratched blocks, resting on the Lower Estuarine Beds (5 to 8).* The Estuarine Beds are very variable in character, alternations of vertical and horizontal carbonaceous markings being frequent. In No. 6, horizontally bedded carbonaceous matter occurs near the bottom. In No. 7, the first foot or so is a good clay with very numerous, black, horizontal lines of carbonaceous matter; below this, however, the bed is more sandy and the carbonaceous matter irregularly disposed.

Weldon.—Some disused ironstone workings to the north of Weldon Grange were next visited, in order to observe the continuity of the various beds seen at Corby, and the changes in some of them. The whole section embraced beds 4 to 9. Here, as at Corby, there is an irregular junction between beds 7 and 8. The total thickness of the exposed beds is very near to the total thickness of the corresponding beds at Corby. A considerable N. to S. fault near here lets down all the beds to the east, so that the ironstone in that direction is too deep to work, even if it were suitable.

Great Weldon Stone Quarries. — The noted freestone quarries at Great Weldon, owned by Lord Winchilsea, were next inspected, by the courtesy of Mr. John Rooke, under the guidance of the foreman of the works. The stone varies a good deal, and much has to be wasted, but when well selected it furnishes a very beautiful stone for ornamental work, of a pleasing colour and good wearing qualities. The total thickness is from 20 to 25 ft. (For full description see Sharp, "Oolites of Northamptonshire," *Quart. Journ. Geol. Soc.*, vol. xxix, p. 234.)

Just outside Weldon is a small roadside section in probably the highest beds of the Lincolnshire Oolite. It is an oolitic rock abounding in fossils, particularly gasteropods. Weldon as a source of Lincolnshire Oolite fossils will be better appreciated on reference to Mr. Hudleston's "Monograph of the British Jurassic Gasteropoda" (*Palæontographical Society*).

Weldon to Dene.—Between Weldon and Dene, in the valley to the south of the road, a small section was examined, showing a very light coloured clay or marl resting directly upon a shelly

* The figures refer to diagram of comparative sections, p. 230.

limestone, almost exactly like that seen a little previously near Weldon, thus fixing the position of this particular zone in this area. The clay represents the Upper Estuarine Beds of the Great Oolite.

Dene.—The section at Dene has been described in three of the works quoted in the list of references, but as none of these correlate the beds with others in the district, or quite agree with the observations of the Director, another is here given. The larger figures refer to the diagram of comparative sections, the smaller to Prof. Judd's description ("Geology of Rutland," *Mem. Geol. Survey*, pp. 101, 102).

			ft.	in.
LINCOLNSHIRE OOLITE.	**3.**	1. Marly limestones	1 to 2	0?
		2. Whitish, calcareous sands	1	6
		3. Hard, blue-hearted, sub-crystalline limestone	1	6
		4. Brownish, calcareous sand, becoming indurated into stone at the base	2	0
		5. Hard and compact coralline limestone, full of *Nerinæa*, with partings of clay	3	0
		6. Irregular bed of silicious concretions with mammilated surfaces below. This bed intensely hard; between its laminæ are numerous plant remains; it appears to be the representative of the Collyweston Slate (Judd)	1	0
	4.	7. Irregularly stratified and false-bedded variegated sand (6 to 8 ft.—Judd) In places almost passes into stone. Intimately connected with No. 3 (6), and at one place rising into it a good deal, therefore thickness variable ...	6	0?
	5.	[Absent]		
NORTHAMTON SAND.	**6.**	7. Light bluish sand, getting much whiter on exposure, with abundant vertical plant markings	3	0
	7.	8. Dark carbonaceous, sandy clay, with masses of iron pyrites, and fragments of wood converted into iron pyrites	5	0
		9. Bed of hard sandstone of a dark grey colour ("Kale" of the workman)	1	0
	8.	10. Light coloured sandy clay...	3	0
	9.	11. Sandy ironstone (dug in a well), 3 to 4 ft.	4	0?
	10.	12. Upper Lias Clay		

EVIDENCES OF UNCONFORMITY.—In a set of beds characterized by an abundance of carbonaceous matter, and therefore of shallow water or estuarine origin, one need not be surprised at evidences of unconformable succession anywhere in the series. The irregular junction between beds 7 and 8 at Corby and Weldon may be taken as evidence of denudation at those places. The horizontally or irregularly-bedded carbonaceous matter in No. 7 and the lower part of No. 6 may be looked upon as evidence of continued erosion not far away.

At Dene, erosion appears to have cut out the whole of Bed 5 and the upper part of Bed 6, as the junction between 4 and 6 is irregular; moreover, the lower part of No. 4 contains

much carbonaceous matter more or less horizontally bedded, probably through the disturbance and re-deposition of the upper layers of No. 6, in which latter the carbonaceous matter is vertically disposed.

For these reasons and others connected with the examination of sections not included in the excursion, bed No. 4 has been placed with the Lincolnshire Oolite and not with the Lower Estuarine series as it is by Professor Judd and Mr. H. B. Woodward.

It is usually assumed that the Lincolnshire Oolite (Beds 2 to 4) was never deposited in the Northampton area, and that there was considerable denudation of the Lower Estuarine beds; the former assumption is probably correct, and the latter requires some modification. A typical section of the Estaurine beds near Northampton would be as below: *

		ft	in.
6.	1. White or bluish grey sands, with some argillaceous matter with vertical plant markings, particularly in lower part	3 to 4	6 to 0
7.	2. Orange and yellow sands. No plant markings ...	4	0
8.	3. Sands almost exactly like No. 1, with vertical plant markings even more abundant	4	0
		12	0

When we compare 1, 2, and 3 with beds 6, 7, and 8 at Corby, Weldon, and Dene, and see that collectively and individually they so nearly correspond in thickness and character (oxide of iron replacing iron pyrites in the middle one), it is scarcely possible to avoid the conclusion of their correspondence. It would thus appear that around Northampton denudation was not greater than at Dene.

Kirby Slate Quarries have not been in work for a great many years, but still the position of the slate beds relatively to the limestone series could be inferred from the nature of the excavation. Specimens of the slate itself were found where the working of it was formerly carried on. The slate usually consists of a single band of stone in the sandy beds (4), or it may, as at Collyweston, constitute the whole of that lithological division.

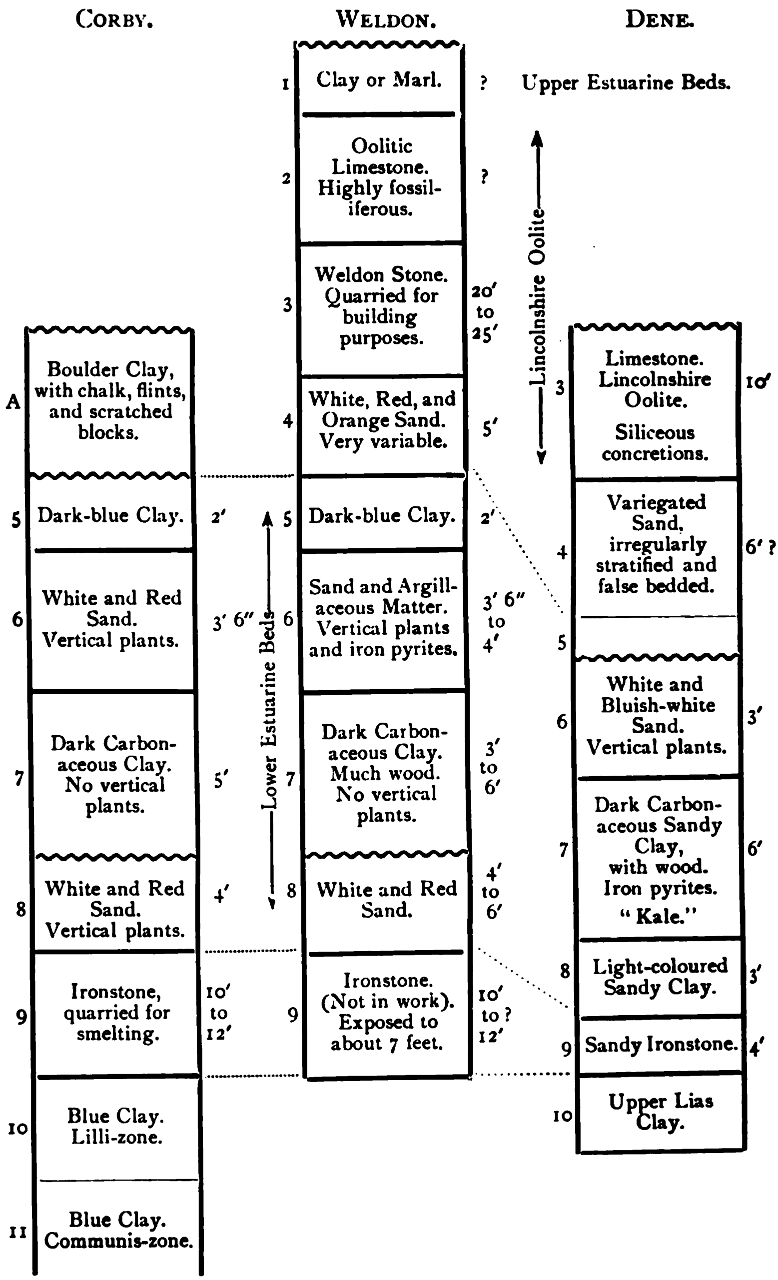
Kirby and Dene Lodge are the most southerly points at which slate has been worked for roofing material.

Gretton.—At Gretton the ironstone workings were examined, but here the Estuarine beds are absent, the ironstone either comes to the surface or is capped by Boulder Clay. The beautiful view across the Welland valley into Rutlandshire received appreciative attention.

Tea was provided at the Hatton Arms Hotel at Gretton,

* See "Excursion to Northamptonshire," *Proc. Geol. Assoc.*, vol. xii, November, 1891 Diagram and page 184), also "The Oolitic Rocks at Stowe-nine-Churches," by Beeby Thompson, F.C.S., F.G.S., *Journ. Northamptonshire Nat. Hist. Soc.*, No. 48, vol. vi, December, 1891.

COMPARATIVE SECTIONS.



and most of the party departed by the train leaving Gretton at 5.28 p.m.

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EXCURSION TO BRITTANY.

WHITSUNTIDE, MAY 18TH TO 24TH, 1899.

Director : CHARLES BARROIS, D.Sc., For. Memb. G.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by* DR. BARROIS, *Translated by* R. S. HERRIES.)

Thursday, May 18th.—The party started from London on May 17th at 8.5 p.m., arriving at St. Malo at noon, when the ladies were all on deck; and the gentlemen were soon employed in making the acquaintance of the French custom house officers. However, in spite of the special facilities arranged for, the train was missed, and Dol was not reached till two hours after the appointed time, a delay which made it necessary to leave St. Marcan out of the programme.

Dol was known in Roman times as *Campi Dolentes*, but the name is evidently the Celtic word *dol*—low-lying, a dale. Dol is, indeed, a low-lying place, built on the old Post-Pliocene shore. The coast about Dol has undergone many changes, and from Dol to Mont St. Michel there is a low and marshy shore, where stand small isolated granitic hills, which have resisted marine denudation better than the surrounding Brioverian shales. The shales are covered by Recent and Quaternary beds, forming a great plain round Mont Dol, which, as well as Mont St. Michel, was an island before the eighth century. It has been calculated that the rate of deposit of sand and silt in this bay has been 16 million cubic feet a year. This marine deposit, which was, to a large extent, reclaimed from the sea by the industry of the inhabitants, was accumulated between the third and eighth centuries. It consists of fine, bluish grey, calcareous clays, with remains of marine shells, which are used for putting on the land. Below is

Alluvium some sixteen feet in thickness with thick beds of peat containing trunks of trees. These peat beds are earlier than the third century, and rest on a grey, compact, calcareous clay, a kind of marine silt belonging, in all probability, to the age of the reindeer.

The Pleistocene period is represented on the coast by raised beaches, which reach a height of about 40 ft. At the disused brickyard at Mont Dol, visited by the party, 800 teeth of *Elephas primigenius* have been found, and are now preserved in the museum at Rennes. Inland the Pleistocene is represented by valley gravels over which is a fine yellow homogeneous loam which is only found on the Channel side of Brittany.

Below these Drift deposits at Dol, are found the crystalline rocks which formed the ancient Pleistocene cliff, well seen inland towards St. Broladre and Roz-sur-Couesnon. They consist of blue shales with beds of grey greywacke, of Brioverian age, which have been rendered spotted, nodular, and micaceous by the proximity of the granitic mass of St. Marcan.

In the midst of these shales, which cover a large area from Plénée-Jugon to Bazouges-la-Perouse, certain round bosses of granite stand out, such as Mont Dol, which was visited by the party, and Mont St. Michel. For a description of these, and an account of their diversity in structure and composition, see p. 117, and Fig. 10, p. 118.

At Mont Dol some fine dykes of ophitic diabase are to be seen, varying in thickness from 3 to 30 ft., such as are scattered over this district, as shown on the geological map. The number of these dykes of Carboniferous age in the neighbourhood of St. Malo is so great that the country must have been covered with continuous outflows of diabase, similar to the basaltic sheets of recent volcanic plateaus. Subaerial denudation has left no trace of this covering.

Near Dol is a famous Menhir, about 30 ft. high and still standing upright; it is situated in a field called "Champ Dolent" distant one mile and a half from the town. The party, before leaving, had a glance at the 13th century cathedral, with finely carved granite porches. They left Dol by train, arriving at Rennes in time for dinner.

Friday, May 19th.—The party made an early start in carriages, accompanied by M. Lebesconte and M. Bezier, who kindly assisted in the direction. Rennes lies in the middle of a great plain composed of Brioverian shales, portion of a large anticlinal fold that has been exposed by denudation. This plain is covered in many places by horizontal patches of Tertiary beds and Post Pliocene brick-earths. The Brioverian shales were seen in some open trenches in the village of Bruz. At Rocher the upper limits of the Brioverian shales are characterised by green flaggy schists. Their junction with the basal conglomerate of the

Cambrian was seen at La Perrière, where the carriages were left.

We now come to a new Silurian syncline parallel to that of St. Aubin d'Aubigné, though it is less deep, as we do not find higher beds than Upper Silurian in the centre, no traces of the Devonian or Carboniferous formations having been preserved. This basin, however, gains in width what it loses in depth, as it is not shut in by imbricated faults, in a narrow trough like the basin of St. Aubin, but extends with gentle undulations over several miles. (See Fig. 4, p. 108.)

The Cambrian rests on the Brioverian at Pont Réan, and its character is well seen in the fine quarries by the side of the Vilaine. At its base is a siliceous conglomerate containing very large pebbles (Poudingue de Montfort), above which are green slates and quartzites, with purple flag-like slates in the upper part, remarkable for their false bedding. They attain considerable thickness, as much as 6,000 feet according to M. Lebesconte, and make very poor land. There are no fossils, except tracks of doubtful origin, known under the names of *Bilobites*, *Vexillum*, etc. At the top is a bed of green slates with *Fucoides rouaulti*, Leb. Along the sides of the valley of the Vilaine the Armorican sandstone is worked in large quarries. It rests on the Cambrian purple slates, and is the oldest formation in Brittany in which fossils have been identified. The fauna, consisting principally of Lingulas and lamellibranchs, indicates a not very deep water origin, resembling that of the Arenig formation. It belongs to the lower part of the Ordovician. The principal fossils besides *Scolithus* and *Bilobites*, are *Ogygia*, *Myocaris*, *Cyrtodonta*, *Ctenodonta*, *Redonia*, *Actinodonta*, *Dinobolus*, and *Lingula*.

The Armorican sandstone, which is some 3,000 feet in thickness, is of great importance in the physical geography of this part of the country, and has largely impressed itself on the landscape of Brittany. It forms the lines of highest elevation of the country, consisting of flat-topped and monotonous plateaus, which are barren except for fir trees. It also forms the chief source of water supply, coming as it does between beds of impermeable shale, which, in contrast to the Armorican sandstone, form fertile plains. The geological map shows that the parallel ridges which form a feature in the landscape are due to repeated foldings of the sandstone.

The sandstone is followed by the Angers slates, which crop out with great regularity in the four synclinal basins between this point and Redon. They are coarse blackish slates with beds of micaceous greywacke and silicified clay nodules containing fossils. There are beds of workable slate which are particularly well developed farther south. For the divisions of this series, see page 109.

At Traveuzot the party collected plenty of fossils from the Sion slates, including *Synhomalonotus tristani*, *S. aragoi*, and *Asaphus guettardi*, from an opening made for the accommodation of the geologists by the Company of the Chemins de Fer de l'Ouest. After a hurried luncheon the members climbed the hill to Laillé, on the top of the Armorican sandstone, where they found the carriages waiting. From this point the road traverses the beds which occupy the middle of this synclinal fold till Poligné is reached, which is on an isolated knoll occupying the centre of the syncline and showing the highest beds of the series. Here are, in ascending order, white sandstones of the same age as the sandstones of St. Germain-sur-Ille, viz: Upper Ordovician overlain by other sandstones, those of Bourg-des Comptes, with ampelites of Upper Tarannon age above. (See pp. 112 and 113, and Fig. 7, p. 111.)

To the south of the hill of Poligné, in the direction of Pléchatel Station, the party crossed in reverse order all the beds seen during the morning. (See Fig. 4, p. 108.) Certain of these beds are particularly well exposed in this district, especially at Riadan, whence the upper slaty division of the Angers slates takes its name, while below in the Chatellier quarry the sandstone of that name is worked, beneath which the Sion slates are well exposed. The route was resumed across the Bagaron uplands, along which the character of the Armorican sandstone is well shown. The Cambrian in this locality is only represented by purple slates a few feet in thickness, this being an example of a phenomenon which is met with over and over again in Brittany in working out the corresponding beds on the opposite sides of the synclinal troughs. Under these purple slates the beginning of a new anticlinal axis of Brioverian shales makes its appearance, on which Pléchatel Station is situated, whence the party took train for Redon.

Saturday, May 20th.—Redon, a curious, mediæval-looking town, is situated at the junction of the canalised river Oust and Vilaine, in the central part of a Silurian syncline. The beds rise on both sides, folded up into two broad anticlinal waves, broken in their centre, where the granitic cores are to be seen.

The members left Redon in carriages, following the Vilaine Valley, too wide for the existing river, and the old remnant of a channel in which the Miocene and Oligocene waters flowed. This is the only locality in Brittany where beds of this age are found.

At St. Jean-la-Poterie the gradual metamorphism of the whole Ordovician series was seen on approaching the granitic core of Allaire. The St. Germain sandstone is not altered, but the succeeding Angers slates become more massive and crystalline, merging into chiastolite slates; the Armorican sandstone follows, but shows hardly any alteration. The actual contact was not

seen, the party coming shortly afterwards on to porphyritic granite. St. Jean-la-Poterie lies on a Pliocene outlier, worked for the manufacture of a most primitive kind of pottery. The clays, with few fossils—*Nassa prismatica*, *N. mutabilis*, *Terebratula variabilis*—are overlain by ferruginous sands and conglomerates.

From St. Jean-la-Poterie the drive was across the bleak granitic plateau of Allaire, which consists entirely of medium grained granite. Leaving the plateau for St. Jacut, on the Ordovician beds to the north, the porphyritic granite is again met with. At St. Jacut the metamorphosed Silurian rocks are found again, but here we meet higher beds in the Silurian series, comprising limestones, ampelites, and variegated shales.

The ampelites are hardened, charged with mica and altered crystals of chiastolite, replaced by green fuchsite. The ferruginous shales of St. Perreux are loaded with specular iron-ore and andalusite. The St. Germain sandstone is changed into quartzite, and the Angers slates into hard, compact, chiastolite slates. The contact sedimentary beds are often crossed by pegmatite veins and aplitic granulites, offshoots from the central massive granite of Allaire. Due attention was given to the atmospheric disintegration, showing massive granite changed into loose sand, for a thickness of more than ten feet.

The party left the margin of the granitoid mass at St. Jacut, and, resuming the route along the main axis, drove to Rochefort for lunch. Rochefort-en-Terre is a small, curious old town, amidst rocky scenery, containing many picturesque old houses of the fifteenth and sixteenth centuries, with a ruined castle, an old church, and narrow, crooked and precipitous streets.

After lunch, the members walked north of Rochefort to the Arz Valley, through the crags of the Angers slates. These slates are remarkably cross-bedded, apparently vertical although nearly horizontal, and are faulted directly against the Brioverian shales. Thus this Rochefort syncline is broken at its edges like the St. Aubin syncline, and nearly all the other synclinal folds of the country.

The Brioverian shales, as seen in the roadsides, are unlike those observed in the neighbourhood of Rennes, being more lustrous, and having some alternating gritty beds with porphyritic quartz crystals. These special characters are not local, but are constant throughout the south-western part of Brittany, where they have been distinguished under the name of shales and arkose of Bains. The contact of these beds with the Lanvaux granite was now gradually approached.*

The party drove back to Redon, over the monotonous Landes of Lanvaux. The scenery becomes more lively and picturesque as Redon is approached, the two rivers here winding among the varied Silurian rocks of the central syncline.

* For the relations of the granitic mass of Lanvaux to that of Allaire, see pp. 117 to 126, and Figs. 12, 13, and 14.

May 21st.—No programme having been arranged for Sunday, the majority left Redon by train in the morning for Auray, in order to visit the celebrated megalithic monuments of the neighbourhood.

The party left Auray in carriages after luncheon, and were joined near the great Plouharnel dolmens by M. Le Rouzic, curator of the Miln museum at Carnac, who kindly acted as guide through the district. The principal object of interest at Carnac is the celebrated Ménec monument. It consists of a vast number of upright stones, varying from 10 to 15 ft. in height, arranged in avenues or parallel lines. At one end of these lines is a circular "Cromlech." These stones were said to have been 11,000 in number, of which only 1,800 now remain. Endless conjectures have been made as to the origin and purpose of this mysterious collection, but at present we have but a poor idea of the religion and government of the ancient inhabitants.

The whole country is commanded by a tumulus on which is built a chapel dedicated to St. Michael, visited by the party on leaving Carnac. The average height of this tumulus is about 30 ft., its base is 350 ft. long by 120 ft. broad. It is of the kind called *Galgal*, and is composed of about 100,000 cubic ft. of rough stones, which have been piled up. It was opened in 1862, and a sepulchral chamber was found at the west end, containing a human skeleton with weapons and ornaments. These relics, as well as many others found in the Druidical monuments of the neighbourhood, are preserved in the local museum at Carnac, to which they were given by Mr. Miln, who collected them. This museum was visited under the direction of M. Le Rouzic, who was formerly Mr. Miln's assistant. It contains also many Roman relics found by Mr. Miln in a Roman villa at Bossenno in the neighbourhood.

From Carnac the geologists proceeded to the grand megalithic monuments of Locmariaquer, crossing the ferry at Trinité-sur-Mer. At Locmariaquer the party visited successively the Men-er-H'roeck, a huge menhir some 70 ft. long, which lies on the ground, broken into three fragments; the dolmen of Mané-Lud, the Table of the Merchants, and the tumulus of Mané-er-H'roeck.

Every dolmen was in the first instance covered by a tumulus—a dolmen being a tomb, as has been proved by the objects found in making excavations. A simple dolmen would be the grave of a single person, while a dolmen with galleries and a covered passage would be the burial-place of a family or perhaps of a dynasty. The clear traces of burials found under the dolmens have proved that these tombs belonged to a race who, like the Egyptians, looked upon their last dwelling-places as abodes for eternity, and built them to last for ever.

Many objects of jade, chloromelanite, and beads found in the dolmens mingled with the ashes of the dead, have been thought

to have been of foreign origin, such as Eastern Europe and Southern Asia, and have been considered as showing that commercial relations must have existed with the East, but recent geological research having shown that most of the substances (under the general name of pyroxenite) occur *in situ* in the cliffs of the Morbihan, this conclusion will seem to geologists somewhat far fetched.

Certain other observations may be made by geologists in studying megalithic monuments; thus it is an invariable rule that they are found in districts where stone abounds, and that they are only constructed with stones from the neighbourhood. Thus the monuments of Locmariaquer are larger than those of Carnac, because the soil of the former consists of gneiss and granite which breaks up naturally into larger monoliths than the granites of Carnac, from which locality gneiss is absent.

Another point is that the examination of certain partly submerged cromlechs in the gulf of Morbihan (er Lanic) shows that there has been an alteration in the level of the land of this region since their construction.

Monday, May 22nd.—The party left Auray by an early train, and in the course of their railway journey, made a second traverse of the country parallel to that of the Vilaine, only in a contrary direction, viz., from south to north. The route follows the valley of the Blavet, and is very picturesque as far as Pontivy, after which near Loudéac it crosses the great plain of Brioverian shales, previously met with in the neighbourhood of Rennes, and becomes dull and monotonous.

Soon after crossing the watershed between the Atlantic and the Channel, the railway traverses the granitic masses of Quintin and St. Brieuc, the detailed study of which was to be the day's work. After having taken up their quarters at St. Brieuc and had luncheon, the party started in carriages to inspect the Quintin mass, first crossing the hornblende-schists and dioritic granite of St. Brieuc.

In the valley of the Urne to the south of Trégueux, the Brioverian shales are exposed with interstratified beds of graphitic chert or phtanites. It was in these chert beds that the Director—in conjunction with M. Cayeux—had found what he believed to be remains of the oldest known Radiolarians. The difference in behaviour of these alternating cherts and shales as they approach the granitic mass of Quintin, and the character of the granulitic gneiss resulting from the alteration of the shales are fully described on pp. 127 and 128. (See Figs. 15 and 16, pp. 128 and 129.)

A very good exposure of the granulitic gneiss was seen in the little valley of St. Julien, south of Péran, and a halt was made at the vitrified camp of Péran, a most interesting object to archæologists. The camp is irregular in shape, some 430 ft. by 350,

surrounded by a rampart with an outer facing of earth 6 ft. 6 in. in height. Excavations made in 1866 led to the discovery that walls of stone had formed part of the construction of the rampart, composed of blocks of diabase, granite, and quartz, and of charcoal cemented together by a glassy paste resulting from fusion, by fire, of siliceous rocks, as has been described by M. Daubrée. Among the antiquities found there, were some which made it seem likely that the Romans made use of this fort while they were constructing the still existing road in the neighbourhood.

The party then returned to the carriages and drove to St. Brieuc, the headquarters for the night.

Tuesday, May 23rd.—The party started in carriages, and proceeded direct to Pointe du Roselier. From the top of the cliffs in the little bay of Port Martin, a fine view was obtained, extending from Roselier across the Bay of St. Brieuc. The Brioverian series is seen in a vertical position, recognisable by the beds of chert which had been seen the day before in the valley of the Urne; but these beds of chert are here interstratified with basic crystalline schists, alternating with the characteristic shales. The composition of this basic series, and its relation to the hornblende-granite of St. Brieuc and the diorite of St. Quay, are fully described on pp. 128 to 131. (See Fig. 17, p. 130.)

The party left Port Martin and drove on without further delay so as to reach the Bay of Bréhec at low water. This bay, where the members had luncheon, exhibits a synclinal structure, belonging to a more northerly fold than all those hitherto traversed by the Association; it is easily distinguished by the composition of the rocks, by the presence of eruptive masses, and by its tectonic structure. It is not a narrow, deep synclinal trough, like those in the south of Brittany, but it is a fold with a flat bottom, consisting of nearly horizontal beds, of which the edges are faulted and crushed. The enclosing rocks belong to the Brioverian series, nearly vertical shales and greywackes, seen on the north and south sides of the bay, those on the south resting on still older mica and chlorite schists and gneisses. These Brioverian rocks are overlain in the bay by beds of Cambrian age, which are entirely separated from them by faults. First we have the magnificent conglomerates of Bréhec, which exhibit at the base of the Cambrian, remains of all the granites and basic eruptive rocks of Brioverian age, as developed between St. Brieuc and Lannion, as well as the schists, quartzites, and cherts of the same series. Resting on the conglomerate are red flagstones and calcareous sandstones, corresponding to the purple slates seen at Pont Réan on the Vilaine. In a short distance these beds become horizontal and are traversed by dykes of orthophyre and porphyrite. They are overlain at Pointe de la Tour by contemporaneous sheets of diabase, which occupy in these cliffs the centre of the syncline.

Above these diabase sheets, near Plourivo, felspathic sandstones of Ordovician age can be seen, which fix the age of the series just described, but they do not crop out in the cliffs of Bréhec. South of the lavas, the other side of the syncline is seen, but it is so much crushed and faulted as to be almost reduced to nothing. This almost complete disappearance, due to mechanical pressure, of the south side of the basin is one of the peculiarities of this section. (See Fig. 5, p. 109.)

The party were rather late in leaving the Bay of Bréhec, and time did not permit of the whole section between Bréhec and St. Brieuc being examined in detail on the return journey. A halt was made at Tréveneuc, and most of the members walked to St. Quay to see the dioritic gneisses and massive diorites of Brioverian age exposed in the cliffs. The drive was resumed from Portrieux to Plérin in the deep valley of the Gouet, where there are excellent exposures of Brioverian mica- and hornblende-schists. Owing to the late hour attention was merely directed to a curious bed of conglomerate intercalated in the series. The pebbles are elongated as though drawn out, and are composed of granite, aplite, and quartz. Though they have lost the rounded form usual in rolled pebbles, they must be considered as clastic on the ground of their mixture in this bed, of their lenticular shape, of their variety in the several overlying beds, of their occasional transverse position, and of their mixed composition. The matrix of the conglomerate consists of quartz, felspar, and black mica, thus having the composition of a felspathic mica schist The contained felspar is not clastic, but authigenic. It is developed in the same way in the schist and graphitic cherts which alternate with the same crystalline schists in the neighbouring cliffs of Roselier. These remarkable conglomerates of Plérin remind one of the well-known gneiss with rolled pebbles at Ober-Mittweida in the Erzgebirge.

In the evening the President (Mr. J. J. H. Teall) tendered a hearty vote of thanks to the Director for the able manner in which he had conducted the geological portion of the excursion; and another vote to Dr. Barrois and Mr. Stebbing for the local arrangements which had given general satisfaction.

Wednesday, May 24th.—Bad weather setting in on the last day of the excursion necessitated a considerable curtailment of the programme. The proposed examination of the beds round Lamballe was abandoned, and the train was taken direct from St. Brieuc to Dinard. Here it was pouring with rain, and geology was limited to an examination of the cliffs on each side of the Rance, at Dinard itself, and at the island of Grand-Bey.

The cliffs of Dinard and St. Malo show a uniform character of gneiss traversed by diabase dykes. These gneisses are altogether different from those seen in the south of Brittany, which have

been considered the oldest rocks in the district. We do not find, as in the gneiss of the South, alternations and regular successions of beds lithologically distinct, gneiss, mica schists, leptynites, and amphibolites, but we have a uniform magma with a granitic structure with constituents in alignment, fibres, ribbons, micaceous and sillimanitic lenticles of amygdaloidal and polyhedric shape (granulitic gneiss). These are held to be the result of a granite (granulite) being intimately injected into shales of Brioverian age, of which the metamorphosed remains would be represented by the micaceous tissues. These tissues give the rock an interlaced character, in which wavy micaceous partings divide the lenticular sheets of massive granulite from each other. The different divisions of the granulitic gneisses in the St. Malo sheet of the map are simply mineralogical. They pass one into the other, and mark the different degrees of metamorphism of the same rocks.

At St. Malo the excursion came to an end, and the party broke up, some returning by the boat to Southampton, some making their way by Mont St. Michel to Normandy, while others started for Laval in order to examine the well-known Devonian beds of the Mayenne Department, under the kind direction of M. and Madame Oehlert.

EXCURSION TO CENTRAL BRITTANY.

Directors: P. Lebesconte and T. Bezier.

(*Report by* Frederick Meeson.)

On *Thursday, May 18th*, a portion of the party visiting Brittany set out from Rennes to examine the fossiliferous Carboniferous and Devonian formations of Central Brittany.

The course taken was by St. Grégoire, Melesse, St. Germain-sur-Ille, St. Aubin d'Aubigné, Andouillé-Neuville, and Gahard.

The Schistes of Rennes, which are identified with those of St. Lo (Brioverian), and correspond with our Longmyndian, were found to be destitute of fossils, and covered by Quaternary gravels, sands, and alluvium.

At St. Gregoire are some Miocene deposits, consisting of calcareous sand (Faluns de l'Anjou) with rolled calcareous nodules. Fragments of *Cidaris* were found.

At St. Germain-sur-Ille are magnificent quarries of sandstone, bearing the name of the place, and differing but slightly from the Grès de May of Normandy. It was pointed out that between Rennes and St. Germain there is, on account of a large thrust fault, an absence of the intermediate deposits found elsewhere in

Brittany. In the quarry occur many intercalations of black micaceous schist, containing the same fossils as the sandstone, and the following were found: *Diplograptus foliaceus* and *Orthis budleighensis*. The graptolitic bed is below that containing *Orthis*. On the northern side of the quarry, the faults had changed the original order of the beds.

The quarry of Carboniferous Limestone, or marble of Quenon, near St. Aubin d'Aubigné was next visited. This limestone is on the same horizon as those of Sablé (Sarthe) and Visé (Belgium), and the sandstone, schists, and porphyroids of the series seen at points on the route are analogous to the so-called Blaviérite de Changé (Mayenne). To the proprietors of the quarry the members were indebted for specimens of the following fossils found in the limestone: *Spirifera*, *Orthis*, *Leptæna*, *Chonetes*, *Euomphalus*, *Productus semireticulatus*, *Fenestella*, *Phillipsia gemmulifera*, and *P. truncatula*.

Passing a long-disused lime-kiln which presented the appearance of a tumulus, the party reached a quarry of the Rocher d'Andouillé-Neuville. This sandstone — designated Grès de Bourg-des-Comptes—is unfossiliferous, and differs in appearance from that of St. Germain. It contains intercalated bands of carbonaceous shale, in which were found *Monograptus priodon*, *M. colonus*, and *Retiolites geinitzianus*.

After lunch at St. Aubin, the course of a stream was followed, in which were exposures of the schists and greywackes of Fret (Finistère) and Greywacke of Faou (Finistère), which overlie the Devonian sandstone. The fossils found included *Leptæna*, *Spirifera macroptera*, *Orthis*, and fragments of Encrinites. Higher up, at the side of the road, were found *Phacops*, *Chonetes sarcinulata*, and *Spirifera*.

The quarry at Grénelais in Grès Supèrieur d'Andouillé, with overlying nodular shales, was next visited, and *Orthoceras*, *Cardiola*, Graptolites, Ostracoda, *Bolbozoë*, and *Primitia* were found. The Calcaires de Rosan, which underlie the sandstone, are wanting here; and the sandstone is overlain by schist with the Wenlock fauna.

The classical ground of La Lézaie was reached, and in a section on the road between Lézaie and Thebaudais-en-Gahard was seen the greywacke of Faou, in which were found *Spirifera*, *Orthis*, *Pleurodictyum problematicum*, and fragments of Crinoids.

The next visit was to a quarry of Grès de la Boë or Gahard sandstone, which is very fossiliferous, *Orthis monnieri* being one of the characteristic fossils.

The last section seen was the grand one of Bois-Roux, in the limestone bearing its name. Amongst the fossils found were *Homalonotus gervillei*, *Cryphæus michelini*, *Leperditia armoricana*, *Bembexia*, *Euomphalus*, *Loxonema*, *Murchisonia*, *Nucula*, *Athyris* (*Spirigera*) *undata*, *Orthis striatula*, and *Rhynchonella fallaciosa*.

The following table gives the order of the beds :

Carboniferous	Limestone of Quenon.
Mid. Devonian	Schists and Greywackes of Fret.
Lower Devonian	Greywacke of Faou.
" "	Limestone of Bois Roux.
" "	Greywacke of Faou.
" "	Sandstones of Gahard and La Boë.
Silurian	Nodular Shales of Grenelais. Sandstones of Andouillé.
Ordovician	Sandstone of St. Germain-sur-Ille, and May (Calvados).
Brioverian	Schists of Rennes and St. Lo.

SUPPLEMENTARY EXCURSION TO LAVAL.

THURSDAY, MAY 25TH, 1899.

(*Report by* R. S. HERRIES.)

IN response to a kind invitation from M. and Madame Oehlert, a party, numbering eleven, travelled from St. Malo to Laval on Wednesday, May 24th, in order to see the fossiliferous beds of that district. After dinner they repaired to the house of M. Oeblert, and were most hospitably entertained by their kind host and hostess.

On Thursday, May 25th, the party started in a brake under the direction of M. Oehlert, being accompanied by Madame Oehlert, and M. Lebesconte, who had come over from Rennes. The route taken was in a northerly direction, following the course of the Mayenne, and at right angles to the strike of the various beds. The following succession of beds in descending order was thus passed over :

CARBONIFEROUS .	Shales. Limestones. Conglomerates.
DEVONIAN . . .	Limestones and shales. Sandstones with *Orthis monnieri.*
? SILURIAN . .	Folded beds.
ORDOVICIAN . .	Slates. Armorican sandstone.
PRE-CAMBRIAN . .	Shales and conglomerates.
GRANITE.	

On reaching the edge of the great granite mass at Montflours the road to the west was taken as far as Andouillé, where a halt was made for luncheon. Just south of the village an opening by the roadside afforded an abundant supply of Ordovician fossils. The beds were now crossed in reverse order, and the next stopping place was at the great limestone quarries of St. Germain-le-Fouilloux, which yielded numbers of Lower Devonian fossils. Two smaller quarries were visited between St. Germain and St. Jean-sur-Mayenne, where the road of the morning was rejoined.

At both these points the limestone was found to be very rich.

In returning a stop was made at Changé to inspect the limestone quarries of Carboniferous age. The party returned to Laval well satisfied with their day's work, and loaded with specimens. At dinner at the hotel Mr. Whidborne proposed a vote of thanks to M. and Madame Oehlert for all their kindness, which was heartily responded to.

On the following morning a visit was paid to the museum, and the exceedingly well arranged local collections were inspected under the guidance of M. Oehlert, after which the members walked to the railway station and left for their various destinations.

EXCURSION TO BUSHEY AND HARROW WEALD.

SATURDAY, MAY 27TH, 1899.

Director: REV. J. F. BLAKE, M.A.

(*Report by* THE DIRECTOR.)

THIS was a cycling excursion in conjunction with the Hertfordshire Naturalists' Field Club, under the guidance of Mr. John Hopkinson.

The members of the two societies met at the chalk-pit on the north side of the railway at Bushey, where they verified the proximity of the outcrop of the Chalk to the Tertiary beds, to be later examined. The horizon of the Chalk here is not the highest in the country, though the highest in this district, as the Tertiary beds overlap different members of the uppermost Cretaceous formation. Above the chalk is here seen a mass of yellow sand, and at its base some large pebble gravel. Elsewhere, above the pebbles came some brick-earth, and it was thought that the purity both of the sand and clay indicated that neither had been moved far, but were the relics of Tertiary strata formerly extending farther northwards than at present.

On the road going south, good exposures were seen in a new excavation of the same coarse gravel at a much lower level indicative that their deposition took place after the main excavation of the valley.

At the Bushey Pit, the basal beds of the London Clay with a band of pebbles was seen, and underneath came the sandy clays of the Woolwich and Reading series with very slight indications of fossils, while at the base were ferruginous sands and pebbles worked for about 8 ft. without approaching the bottom. On one side of the pit were observed some curious bands of whiter rock more compact and calcareous than usual, which not being seen on the opposite side of the pit, were taken to be a local variation of the Woolwich beds.

Thence the party adjourned to the pit in the same rocks at Watford Heath, where they inspected the fossils collected there by the late proprietor, Mr. Stone, then a member of the Association, and kindly exhibited by his son. Here also the pebbly Basement Bed of the London Clay was seen, and it was understood that from it the shark's teeth and oysters exhibited had been obtained, the members themselves verifying the fossiliferous character of the bed. Here the underlying sands were much better developed, and they are very pure and white. They go down far beneath the level of the quarry, some 14 ft. it was said, and it was rendered probable that they do so by the fact that though chalk is required at the kiln it is found more advantageous to cart it from Bushey than to seek for it on the ground itself.

After inspecting the quarry the members rode south over the London Clay by Greame's Dyke to "the City," where they had tea and then dispersed.

EXCURSION TO RICKMANSWORTH AND HAREFIELD.

SATURDAY, JUNE 10TH, 1899.

Directors: W. WHITAKER, B.A., F.R.S., Pres.G.S., AND JOHN HOPKINSON, F.G.S., Assoc.Inst.C.E.

Excursion Secretary: A. C. YOUNG, F.C.S.

(*Report by* J. HOPKINSON.)

SOME of the finest and most instructive sections of the Upper Chalk in the neighbourhood of London are to be seen at Harefield, where, facing the Grand Junction Canal in the valley of the Colne, there are three large chalk-pits within a distance of a mile and a half, permission to visit which had been obtained.

Ascending a hill half a mile south of Rickmansworth, a very fine view of the valleys of the Colne, Chess, and Gade was obtained. The hill is capped by a thick bed of gravel, one advantage of which, Mr. Whitaker remarked, is that we may call it what we like and no one can contradict us, for it may be almost anything. He could only say that it was a pebbly gravel, as coloured on the Geological Survey Map. He believed that it was not Post-Glacial, and that it had nothing to do with the existing river in the valley below. In this valley water-cress beds might be seen, fed by springs from the Chalk, and sometimes by borings being made to obtain an increased supply of water.

Less than another half mile to the south is Woodcock Hill Kiln, and here the mottled plastic clays of the Reading Beds were seen surmounted by the Basement Bed of the London Clay,

consisting of sandy clay and loam with a layer of flint-pebbles in the middle. Below the mottled clay are fairly-white and brownish sands, and resting in hollows in the London Clay is a clayey gravel. The mottled clays were seen to hold up water which percolates through the sandy bed above it.

A pleasant walk of two miles across the fields brought the party to Harefield, where tea was partaken of at the "King's Arms." The Harefield Brick and Cement Works, just beyond the southern end of the village, were then visited. There is here a very fine section of the Chalk, Reading Beds, and London Clay with its Basement Bed, which has been described by Mr. Whitaker in the *Geology of London*, vol. i, p. 196.

The section is now rather clearer than it was when this description was drawn up. The mottled clays of the Reading Series are fully exposed, and the grey sand and clay appear to have a considerable extent. The only foreign rock seen in the bed of flint-pebbles (at the bottom) was an iron-sandstone, rather friable. Mr. Whitaker remarked that this bed was much like the Hertfordshire pudding-stone, except that it was not in Hertfordshire and was not a pudding-stone. It was in Middlesex, but close to the Herts. border, and although the pebbles were not consolidated with silica, there was silica present in the form of sand.

Several fossils were obtained in the Basement Bed of the London Clay. Shells chiefly occur in masses, but not in a good state of preservation.

Passing the Asbestos Mills, formerly, as marked on the Ordnance Map, the "Copper Mills," the Harefield Lime Works were visited.* Here there is a section of the Upper Chalk nearly 100 ft. in height giving a better illustration of the phenomenon of "pipes" than is to be seen elsewhere within many miles of London. It was quite clear, Mr. Whitaker said, that the irregular masses of loose sand and gravel which extend downwards from the top of the pit had really been let down from above. No surface-action could have formed them ; the chalk had evidently been dissolved away by water percolating through fissures, and the sand and gravel had gradually taken its place. The chalk was seen to be quite evenly bedded.

Crossing the fields to the Springwell Chalk Pit, it was noticed that the chalk was very little fissured by pipes, this being due to a bed of comparatively impervious clay on the top.† Although this pit has been worked for at least thirty years it is not marked on the 6 in. Ordnance Map.

After a hearty vote of thanks to the Directors, a short walk along the towing-path of the canal brought the party to Rickmansworth Station, those who returned to London leaving by the 8.10 train.

* See Plate VI, vol. vii, *Trans. Herts. Nat. Hist. Soc.*
† See Plate VI, vol. vii, *Trans. Herts. Nat. Hist. Soc.*

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EXCURSION TO LICHFIELD AND CANNOCK.

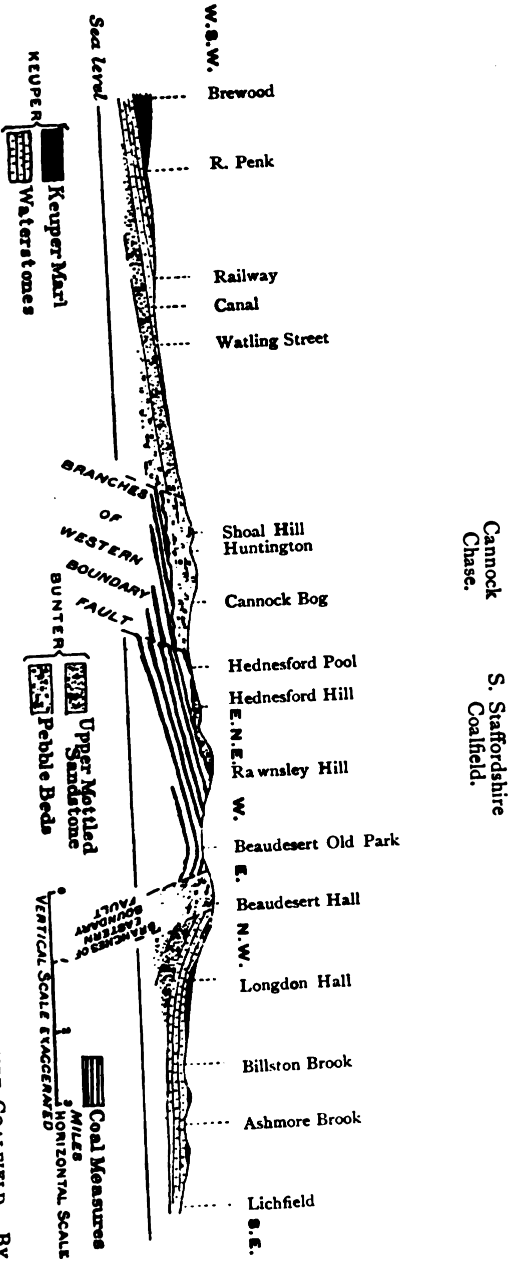
SATURDAY, JUNE 17TH, 1899.

Directors: PROF. C. LAPWORTH, LL.D., F.R.S., AND PROF. W. W. WATTS, M.A., F.G.S.

Excursion Secretary: A. C. YOUNG, F.C.S.

(*Report by* THE DIRECTORS.)

THE members reached Lichfield at about twelve, and a few minutes were spent in the Cathedral, the salient points in the architecture of which were explained by Mr. Frank Raw. After driving out from Lichfield the first halt was made below Lysways Hall, where a dam has been constructed by the South Staffordshire Waterworks Company, impounding the water of the Billston Brook and its tributary, the Ben Brook. The features of the drainage basin were pointed out by Mr. Hill, who accompanied the party. Re-entering the carriages the party were next driven across the New Red Marl and Waterstones to the entrance to Beaudesert Park, near to which occurs the more easterly branch of the eastern boundary fault of the South Staffordshire Coalfield, which brings up the Bunter Pebble Beds on the west to the horizon of the Waterstones on the east (see section). The members, by kind permission of Mr. Sugden, walked through the lovely scenery of the Park, founded on Pebble Beds, to the camp, which gives an extensive prospect over the northern portion of the South Staffordshire Coalfield. A second branch of the eastern boundary fault of the coalfield skirts the eastern side of the camp, bringing up the Coal Measures on the west into contact with the Pebble Beds of the east (see section). Looking out over Beaudesert Old Park, now converted into a flourishing coalfield, Profs. Lapworth and Watts pointed out the general structure of this part of the coalfield, drawing especial attention to the work of Jukes in establishing the fact that the Thick Coal of the southern part of the coalfield is split up into several seams, separated by hundreds of feet of measures in the northern part. Many of these seams are being worked in the collieries about Beaudesert, Rawnsley, Hednesford, and Cannock.



SECTION FROM BREWOOD TO LICHFIELD ACROSS THE NORTHERN PORTION OF THE SOUTH STAFFORDSHIRE COALFIELD. BY PROFS. LAPWORTH AND WATTS.

The drive next crossed the northern tongue of the coal-field as far as Scout House Reservoir, and from this point for some distance, the rising ground on the north of the road is occupied by Pebble Beds, exposed in many quarries, while to the south the brick-clays belonging to the Coal Measures, lying unconformably below, were being worked in numerous large excavations (see section). The first branch of the Western Boundary Fault was crossed north-east of Cannock, and the rest of the journey to this town was over Pebble Beds.

At Cannock the party was most hospitably entertained at tea by Mr. C. A. Loxton, LL.B., of Shoal Hill House.

A somewhat hurried drive to Stafford took the party near the huge excavations in the Pebble Beds of Cannock Chase, the pumping station of the South Staffordshire Waterworks Company, and past Huntington Colliery, where a sinking through the Pebble Beds has been successful in finding coal.

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EXCURSION TO ALDRINGTON, BRIGHTON, AND ROTTINGDEAN.

SATURDAY, JUNE 24TH, 1899.

Directors: F. CHAPMAN, A.L.S., HENRY EDMONDS, B.Sc., AND C. DAVIES SHERBORN, F.Z.S.

Excursion Secretary: A. C. YOUNG, F.C.S.

(*Report by* C. D. SHERBORN.)

MR. FREDERICK CHAPMAN having kindly consented to explain the Aldrington section (see PROCEEDINGS, p. 259), a small party left London by the early morning train, and had the opportunity, therefore, of comparing the Raised Beach and Elephant Bed at this end of Brighton with that originally described by Mantell to the east of Brighton. Meeting the main body in the afternoon, the Directors led the way to the shore, where Mr. Chapman explained the Pleistocene section, which at this point is:

Soil, etc.		
Pleistocene	Elephant Bed	50 to 60 ft.
	Old sea-beach	5 to 8 ft.
	Sand	3 to 4 ft.
Chalk		

The "Elephant Bed" rests on the Chalk, which is more or less horizontal in the section, and so continues to Rottingdean. The Chalk belongs, according to Barrois, to the "Assise à Belemnitelles," which, he says, forms part of the "Zone à Marsupites." The characteristic fossils given in "Terrain crétacé supérieur," are, among others: *Micraster cor-anguinum*, *Offaster* (*Cardiaster*) *corculum*, *Rhynchonella plicatilis*, *Belemnites merceyi*, *Inoceramus lingua*, *Terebratulina striata*, crinoids, cidarids, sponges, etc. Large Ammonites (*A. leptophyllus*) are very common in the cliff and on the shore, and a magnificent specimen from this locality has lately been exhibited in the British Museum (Natural History) Marsupites also occur, but on the outward journey the party were unable to find specimens, though some were secured on the return journey, from the shore, in the position pointed out by the Directors. The liberality also of the landlord of the "White Horse," Rottingdean, enabled several members to secure more or less perfect specimens.

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EXCURSION TO CUXTON AND BURHAM.

SATURDAY, JULY 1ST, 1899.

Director: G. E. DIBLEY, F.G.S.

Excursion Secretary: A. E. SALTER, B.Sc., F.G.S.

(*Report by* THE DIRECTOR.)

The members arrived at Cuxton at 11.15 a.m., and visited a pit a quarter of a mile south of the station, by permission of Messrs. Weekes & Trechmann. The Director remarked that on their journey from town they had passed over the highest zones of the Chalk in the London area, at Gravesend and Farningham Road. At Strood, they had seen Upper Chalk of a decidedly low-zonal character, the predominant fossil being *Micraster coranguinum*, with *Echinoconus conicus*, and in the two and a half miles from Strood to Cuxton successively lower zones formed the outcrop, so that it could be distinctly seen that the beds have a somewhat north-easterly dip. At Cuxton, the whole of the Chalk (over 200 ft.) was certainly below the *M. coranguinum* zone. Flints occur in the upper half of the section. The typical fossils are the *Holaster planus*, *Terebratulina*

gracilis, *Rhynchonella cuvieri*, and associated with this zone, the Director pointed out that he always found *Pentacrinus*. A diligent search was then made over the flint heaps and members were rewarded by the finding of the above-mentioned typical fossils in addition to *Micrasters*—intermediate in form between *M. corbovis* and *M. coranguinum*—*Spondylus spinosus*, and two foreign pebbles.

The next pit, half a mile southward, belonging to Messrs. Formby & Co., revealed a section lower in the Chalk, and in a pit a little to the east still lower beds were seen. The latter pit was entered by a cutting, in which a fine section of hill-wash resting on valley gravel occurred among the chalk. On the way to Halling Ferry, the Director exhibited two very fine palæolithic and one neolithic implement from the gravel of the neighbourhood, also a fine specimen of *Radiolites mortoni*, Mant.

On turning out of the village street at Wouldham, the extensive pits of Messrs. Peters and Co. stood out prominently, the *Belemnitella plena* zone being very conspicuous; these pits are situated at a higher level than those just left, showing that here the Chalk is folded or faulted.

At Blue Bell Hill pit the members beheld a magnificent exposure of Chalk (in the upper pits 300 ft. in depth) containing the *H. planus*, *T. gracilis* and *R. cuvieri* zones, and in the next pit is seen, in direct succession, the *Inoceramus mytiloides* band resting on the *B. plena* zone, both fossils being found *in situ*, with about 170 ft. of Lower Chalk, and this again, followed by a fine cutting in the Chalk Marl, comprised a section which has no equal in the London area. In the lower pit, *Holaster subglobosus* is the typical fossil, while from the Chalk Marl *Rhynchonella mantelliana* and Cephalopods are frequently obtained.

The pits were then entered and a goodly number of fossils obtained, together with a fine piece of sandstone, wood and calcite. The members then climbed to the top of the hill, where a grand view of the valley was obtained, with the Medway cutting through the Gault (as seen in the Burham Brickfield), and the Greensand and Wealden beds beyond. Shortly after, descending the hill towards Aylesford, the sarsens comprising "Kits Coty," and the so-called "countless stones" (of the same material) in a field below were inspected, also an exposure at Aylesford in which the Folkestone Sands were seen capped by valley gravels.

After tea at the George Hotel, the President, in proposing a vote of thanks to the Director, referred to the work of Dr. Barrois, Dr. Rowe, Mr. C. D. Sherborn, and the Director, on the Chalk of the district. Mr. Sherborn and the Director replied, and a vote of thanks was passed to the proprietors of the pits which had been visited.

CYCLING EXCURSION TO THE CHILTERN HILLS.

SATURDAY, JULY 8TH, 1899.

Director: H. J. OSBORNE WHITE, F.G.S.

Excursion Secretary: A. E. SALTER, B.Sc., F.G.S.

(*Report by* THE DIRECTOR.)

THE party assembled at West Wycombe Station early in the afternoon, and proceeded westward along the Oxford Road. Just beyond the village, the Director commented on the patch of gravel capping the ridge in the vicinity of the church. The gravel, situated about 520 ft. above O.D. (or 230 ft. above the valley-floor at West Wycombe), is no doubt, of fluviatile origin, and like the low-level valley gravels of the immediate neighbourhood, consists essentially of flints in different stages of attrition. The absence of the durable, and easily recognisable "lydite" pebbles, characterising the Lower Greensand and Portland Beds out-cropping to the north-westward of the Chalk escarpment, in the gravels of the Wye and other breaching transverse valleys of the western Chilterns, furnishes a strong argument against the view that the streams occupying these valleys formerly drained the older rocks exposed in the Thame basin, and were there beheaded by "subsequent" branches of the Thames developed along the strike of the weaker strata.

Ascending Dashwood Hill, where the road-cutting exposes some small pipes filled with brown clay-with-flints, the party gained the Chalk plateau, across which a wide view of alternating ridge and valley was obtained to the north-eastward. The even outline of the ridges appears to be due to the local absence of the mound-like Tertiary outliers on the gently sloping platform of Chalk, rather than to any former base-levelling the region may have undergone. Leaving the Oxford Road a little short of Stokenchurch, the dip-slope was followed down to Cadmore End Common; where a short stoppage was made to examine a pit showing a few feet of mottled sandy clay, underlain, at one spot, by a lenticular mass of white angular flints, with a few pebbles of flint, quartz, and dark chert, in a loamy matrix. This deposit, which occurs at the northern boundary of the Lane End Eocene outlier, appears to have formerly filled a small valley, whence it has been partially removed, and it is evidently the result of local wash; the pebbles and mottled loam being derived from the adjacent Reading Beds and pebbly ("Westleton") gravel, and the angular flints from the Chalk plateau.

Near Bolter End, a good section of a flint pebble-bed, closely resembling the Blackheath Beds to the south and east of London, but here, apparently, forming part of the Reading Series, was seen in a field on the south side of the road. The Director remarked on the scarcity of such masses of pebbles in the

Lower Eocene beds on the north side of the London Basin, and on the small horizontal range of the deposit in this outlier. The section showed a depth of about 7 ft., but, judging by surface indications, the actual thickness of the bed must be quite three times as great. Between Bolter End and Lane End an example of Prestwich's Westleton Shingle, which caps the London Clay on the main mass of the outlier (above 600 ft. O.D.), was noticed. Its composition is as follows: Flint pebbles; subangular, and a few angular flints; small white and pink quartz pebbles, and some small pieces of dark, compact, Carboniferous chert. A good specimen of the last-named, with impressions of small encrinite stems, was found by Mr. Salter. While the flints may well have been derived from the Chalk and Tertiary rocks of the region, the immediate sources of the rest of the materials of this gravel is still a matter of uncertainty.

By the side of the road leading from Lane End down to Moor Common the party inspected two sections showing about 15 ft. of light greyish sand, with some thin beds of bluish pipe-clay, ironstone, and a layer of flint pebbles near the top, forming the upper part of the Reading Beds. The London Clay, which comes on immediately above, has been disturbed by human agency; but numerous septaria were to be seen on the spoil heaps hard by, together with slab-like masses of the bottom bed of that deposit, crowded with casts of shells.

From a spot on the edge of the Common, the Director drew attention to the effects of the disturbances and dislocations of the strata on that side of the Lane End outlier. The London Clay and Reading Beds they had just seen on the slope behind them ran down into the bottom of the valley across which they were looking, while the Chalk occurred at a higher level on the north, west, and south. The contrast between the hummocky, gorse-covered and wooded surface of the sands and clays, and the open, smoothly-swelling slopes of the limestone was, in many places, very sharply marked. Mr. Whitaker's explanation of this unusual state of things, viz., that the strata had been here troughed and let down *en masse* between two pairs of sub-parallel faults intersecting each other at nearly right angles, seemed to meet the main requirements of the case satisfactorily. The maximum vertical displacement was probably not less than 150 ft. An interesting result of the disturbances referred to had been the production of a local north-westerly drainage—the valley excavated along the faulted mass sloping rapidly in that direction (*i.e.*, against the general inclination of the country), to join the Hambleden valley at Fingest.

Crossing the Common, the Director led the way on foot through Moor End Wood to a swallow-hole with precipitous sides, which receives the drainage of the adjoining slopes. The small streams flowing off the southern end of the Common have cut

deep channels through the Eocene clays and sands into the Chalk, over which the water runs in a succession of miniature falls—to vanish in the apertures plainly visible round the sandy floor of the hollow. The members of the party were not a little impressed by the realisation of the enormous amount of rock-waste that had been here carried down into the Chalk.

Ascending the western slope of the valley, by Frieth, the ride down the dip-slope was resumed, through Parmoor and Rockwell End, where a small plateau of gravel (450 ft. O.D.) composed of partially worn flints and a few flint pebbles was noticed. In Heath Wood (350 ft. O.D.) the zone of gravel with Triassic *débris* bordering the Thames valley was entered; and, a little further south-east, the characteristic quartzite pebbles were easily recognisable on the fields about Bockmer (336 ft. O.D.). Descending the steep slope of the Thames valley to Medmenham the members observed the clear spring thrown out at the roadside by the Chalk Rock. Proceeding thence along the Reading Road the next stoppage was made at the quarry north of Westfield Farm, showing a fine section of the Chalk Rock, overlain by about 20 ft. of Chalk with layers of flint nodules, and passing down into grey, massively-jointed, flintless chalk, used for building stone in the neighbourhood. The junction of the Upper and Middle Chalk is marked by a thin band of brown, marly clay, containing comminuted flints.

Turning to the left near Mill End, the party crossed the Thames at Aston Ferry, and, after taking tea at the "Flower Pot," rode on to the pits above Remenham. The first of these exhibits about 30 ft. of the lower part of the Upper Chalk, much piped with gravel from above. The second, at a higher level, exposes a good section, 10 ft. in depth, of well-stratified gravel, containing a large proportion of material foreign to the rocks of the London Basin; amongst which the red and grey quartzites from the Bunter Beds are very prominent. Near the base of the section the gravel becomes coarser, and contains rounded blocks of red and buff sarsenstone up to a foot in diameter. Here and there the bedding planes curve downward rather sharply, indicating the position of pipes in the subjacent Chalk. The gravel exposed in this pit forms a finely developed river-terrace, at about 70 ft. above the Thames, occupying a convex spur of the valley slope. From the bank of the pit the members at once recognised the resemblance this even terrace, backed by rising ground to the south, bore to the spreads of low-level alluvium bordering the modern river: a resemblance rendered more than usually pronounced by the slight depression separating the small plateau from the slope beyond, corresponding to the backwater which, in this district, is so often found skirting the wider expanses of water-meadows through which the main stream wanders. The Director observed that the Thames here ran in an

intrenched meander cut in the floor of an older and wider valley, whose limits were almost obliterated; and indicated the following localities on the surrounding slopes where relics of older terraces had been preserved, viz., near States Farm, above Medmenham, 150 ft.; No Man's Hill and White Hill, respectively north-east and south-west of Henley, between 200 and 250 ft.; Bockmer, 250 ft.; and near Fawley, 350 ft. above river-level.

After an animated discussion on the significance of the form of, and direction pursued by, the Thames valley in this locality, a cordial vote of thanks, proposed by Mr. Hopkinson, was awarded the Director, and the party dispersed.

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EXCURSION TO GUILDFORD AND GODALMING.

SATURDAY, JULY 15TH, 1899.

Director: A. K. COOMARA-SWAMY, F.G.S.

Excursion Secretary: A. E. SALTER, B.Sc., F.G.S.

(*Report by* THE DIRECTOR.)

THE objects of the excursion were to trace the succession from London Clay to Weald Clay, and to see the Peasemarsh anticline.

The party left Waterloo at 1.5 p.m., and proceeded along the Godalming Road to St. Catherine's Hill (Folkestone Beds). There the Director pointed out the geological features of the district, viz.: the line of escarpment of the North Downs and the Hog's Back; the Guildford Gap, through which the party had just passed; and the Lower Greensand escarpment, the deep southern slope of which is due to the outcrop of the Bargate Stone.

Descending the hill, an old quarry in the Bargate Stone on the road to Littleton, was inspected. Proceeding along the footpath, a new section at the top of the second field was

visited. The section shows the lower part of the Bargate Stone, and the top of the Sandgate Beds, and is fossiliferous. The footpath along the top of this field (on the surface of which remanié fish teeth may be found) was followed to a quarry showing Bargate Stone and Sandgate Beds, which has been described by C. J. A. Meÿer on p. 11 of his *Lower Greensand of Godalming*.

Passing through Littleton, a halt was made at Littleton Brick-kilns, where the following section was seen, by kind permission of Mr. F. Mitchell:

	ft.	in.
Soil and weathered Clay	4	6
Ironstone Nodules with Atherfield Fossils	1	0
Brown Clay	2	3
Blue (Wealden) Clay, seen	5	6

The following fossils from the nodules have been kindly identified by Mr. H. A. Allen: *Serpula*, *Enallaster fittoni*, Forbes, *Terebratula* sp., *Exogyra* sp., *Pecten quinquecostatus*, Sow., *Pecten* sp., *Perna royana*, D'Orb., *Arca raulini*, Leym., *Modiola cornueliana*, D'Orb, *Modiola* sp., *Nucula* sp., *Cytherea parva*, Sow., *Panopæa plicata*, Sow., *Thetis sowerbyi*, Röm., *Cerithium* sp., *Aporrhais* sp.

Proceeding across the axis of the Peasemarsh anticline to Binscombe, the southern outcrop of the Bargate Stone was ascended, and the Frith Hill section in the Hindhead Road examined. The Director exhibited some of the remanié fish teeth which are found in the pebble beds in this section. They include *Lepidotus*, *Pycnodus*, *Gyrodus*, *Strophodus*, *Lamna*, *Acrodus*, *Hybodus*, and *Sauricthys*? The beautiful preservation of some of the Hybodont teeth, with their points scarcely at all worn, is noteworthy. The Director had found similar rolled fish teeth in the ferruginous sands near Atherfield, I.W. The upper part of this section shows Bargate Stone and pebble beds interstratified. In the lower part the Bargate Stone dies out, lower still the pebbles become less frequent, and the somewhat clayey sands of the Sandgate beds are seen. After finding a few fish teeth, the members proceeded to the Angel Hotel, Godalming.

After tea, Mr. Herries proposed a vote of thanks to the Director, who replied, and the members returned to London by the 7.35 train.

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EXCURSION TO CLAYGATE, CHESSINGTON, AND OXSHOTT.

SATURDAY, JULY 22ND, 1899.

Director : W. P. D. STEBBING, F.G.S.

Excursion Secretary : A. E. SALTER, B.SC., F.G.S.

(*Report by* THE DIRECTOR.)

At Mr. Sims's brickfield, Claygate, a very good section of the upper part of the London Clay merging upward into the Lower Bagshot sands was seen, and, at the base, typical London Clay with septaria, in some cases full of shells. The hard ferruginous layer, forming an iron pan, Mr. Herries considered to be the junction between the London Clay and the Lower Bagshot sands. The clay, greyish in colour at the bottom, becomes browner towards the top, and is very finely laminated. The proportion of sand increases towards the junction, so that the highest beds are too sandy for brickmaking. The section showing the Lower Bagshot consists of buff and yellow sands with a few partings of clay.

After Professor Blake had thanked Mr. Sims for his kindness, the party returned to Claygate. Thence they proceeded south eastwards to Mr. Welsh's brickfield, where the beds are very much folded and contorted. The Director thought the foldings and contortions might be due to landslips, but Mr. Herries suggested that they might be due to lateral pressure. This section, although in the same ridge as the former, showed stiff laminated clay without any sand, and no septaria.

The party next proceeded south eastward to Mr. Sayers's brickfield on the Surbiton and Leatherhead road. On the way, at the top of the ridge (241 ft. O.D.) capped with Bagshot Beds, the clay-bed of a small dried-up pond was seen; the sides showed flint pebbles and Lower Greensand chert, furnishing conclusive evidence, Mr. Herries said, of Prestwich's Southern Drift.

The shallow excavation in London Clay in Mr. Sayers's brick-field is interesting on account of the large size of the septaria which occur in a bed dipping N.W. A piece of wood bored by *Teredo* was found. From this spot the party took the path direct to Oxshott Station. About half way along the road a well-sinking had been commenced, and the spoil heap showed dark blue London Clay with selenite and shells.

After tea Mr. Herries tendered a vote of thanks to the Director for a very pleasant afternoon, and the members left by the 7.37 train for London.

NOVEMBER, 1899.]

EXCURSION TO CHARLTON, ERITH, AND CRAYFORD.

SATURDAY, SEPTEMBER 9TH, 1899.

Director: W. WHITAKER, B.A., F.R.S., Pres. G.S.

Excursion Secretary: A. E. SALTER, B.Sc.

A LARGE party met at Charing Cross Station and, accompanied by members of the Société Belge de Géologie, journeyed to Charlton by the 10.2 train in order to examine the fine exposures of Thanet Sand and Chalk* in the neighbourhood. At 12.56 the excursion was continued to Erith and Crayford, where the numerous sections of Chalk, Thanet Sand and Drift were inspected. The last afforded a large series of mollusca and some fragments of bone, including the neural spine of a vertebra of *Elephas* found by one of the visitors.

After lunch the President offered a cordial welcome to the Belgian geologists. M. Mourlon, President of the Belgian Society, replied in French, thanking the Geologists' Association for the instructive excursion so ably directed by Mr. Whitaker. Dr. Kemna, in most genial terms, gave a free translation of this reply.

VISIT TO THE BRITISH MUSEUM, JERMYN STREET MUSEUM, AND NATURAL HISTORY MUSEUM.

MONDAY, SEPTEMBER 11TH, 1899.

Excursion Secretary: FREDERICK MEESON.

AT 10 a.m. a visit was paid to the BRITISH MUSEUM, where the party, including members of the Société Belge de Géologie, were kindly conducted through the Prehistoric, Ethnographical, American, and Egyptian galleries by Mr. C. H. Read.

THE MUSEUM OF PRACTICAL GEOLOGY was next visited, where the geologists were received by the Director of the museum (Sir A. Geikie) and the Curator. Sir Archibald Geikie here undertook the direction of the excursion, and drew attention to the more interesting exhibits in the Hall, on the Principal Floor, and in the Palæontological and Rock galleries.*

On the motion of M. Mourlon, a hearty vote of thanks was accorded to the Director, who replied in felicitous terms.

The geologists then made their way to the BRITISH MUSEUM (NATURAL HISTORY), where Dr. Henry Woodward and Mr. A. Smith Woodward kindly conducted the party through the magnificent Geological Collection.*

* For a description of the sections and museums visited, see papers mentioned in the references.

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1897. WOODWARD, Dr. H.—"Visit to the British Museum (Natural History)." *Proc. Geol. Assoc.*, vol. xv, p. 85.

1898. "Visit to the Museum of Practical Geology." vol xv, p. 287.

ORDINARY MEETING.

FRIDAY, JULY 7th, 1899.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

The following were elected members of the Association: E. Philip Barber, Alfred James, F.G.S., Miss Hester Pengelly, Dr. A. W. Rowe, F.G.S.

The following paper was read:

"A Sketch of the Geology of the Lower Carboniferous Rocks of Derbyshire," by H. H. ARNOLD-BEMROSE, M.A., F.G.S. Illustrated by Lantern Slides.

THE RAISED BEACH AND RUBBLE-DRIFT AT ALDRINGTON, BETWEEN HOVE AND PORTSLADE-BY-SEA, SUSSEX. WITH NOTES ON THE MICROZOA.

By Frederick Chapman, A.L.S., F.R.M.S.

(*Read June 2nd*, 1899.)

I.—INTRODUCTION.

THE Raised Beaches of the Sussex Coast have been the subject of many valuable papers and memoirs, such as those by Mantell, Murchison, Dixon, Godwin Austen, Prestwich, Clement Reid, and others. So far, however, these deposits of the South Coast have never been systematically investigated for their microzoa.

The minute organisms from the Raised Beaches and Estuarine Clays of Scotland and Ireland, which are of later date than similar deposits of the South Coast, have been studied and well described by G. S. Brady, Crosskey, Robertson, J. Wright, and others. In the South of England, we have merely a few species of Ostracoda and Foraminifera recorded from the Raised Beach and "Head" of Portland Bill and Chesilton ;* and some Foraminifera from a Beach Deposit in Goodwood Park, Sussex.†

From the Raised Beach at Portland Bill, Gwyn Jeffreys determined *Miliolina seminulum* and a species of *Cythere* ; ‡ and to these Prof. Rupert Jones has added *Polystomella striatopunctata* and a *Cythere* sp. nov. ? ||

From the angular rubble-bed at Portland Bill, Mr. Etheridge reports "*Cypris striatopunctata* and *C. legumen* or *fasciculata*."§

At Chesilton two species of Ostracoda were found in the Rubble or "Head," viz., *Cypris* [*Scottia*] *browniana* and *Candona candida*. Also Foraminifera (not specified).¶

From the marine sands in a sand-pit at the S.E. corner of Goodwood Park, Sussex, Prestwich has recorded the occurrence of the following foraminifera : ** *Truncatula* [*Truncatulina*] *lobatula*, *Rosalina* [*Rotalia*] *beccarii*, and *Nonionina asterigerina* [?], as determined for him by Messrs. Jones and Parker. In the same bed of sand these additional fossils occurred : *Mytilus edulis*,

* Prestwich, *Quart. Journ. Geol. Soc.* vol. xxxi (1875), pp. 33, 34, 37, and 39.
† *Idem*, *ibid.*, vol. xv (1859), p. 219.
‡ *Idem*, *ibid.*, vol. xxxi, p. 33.
|| *Idem*, *ibid.*, vol. xxxi, p. 34.
§ *Idem*, *ibid.*, vol. xxxi, p. 37.
¶ *Idem*, *ibid.*, vol. xxxi, p. 39.
** *Idem*, *op. cit.*, vol. xv p. 219.

Cardium edule, *Pholas dactylus* [?], *Purpura lapillus*, *Balanus porcatus*, and *Echinocyamus pusillus*.

Having lately had some opportunities for examining a good section of the Raised Beach exposed in a sand-pit between Hove and Portslade, I collected material from various levels, to investigate with the microscope, and was rewarded by some very interesting results, which seem to throw additional light on the history of these particular deposits.

When Mantell described the Raised Beach and Elephant-Bed in the neighbourhood of Brighton,* the sections exposed along the coast to the east of that town were much more extensive than now. Beyond Black Rock there still remains, however, a great part of the exposure of the Pleistocene deposits so well depicted by that author.

On the west of Brighton, by way of Hove, Portslade-by-Sea, and Southwick, the Raised Beach and Rubble-Drift, although not of so great a thickness as to the east, is also clearly seen in the various sand-pits and cliff-sections.

The cliff section towards Hove from Brighton, where the superficial beds sink almost to the level of the present beach, was described in some detail by Sir Roderick Murchison in 1851.† He also records finding *Mytilus edulis* and *Littorina littoralis* (= *L. obtusata*) in the Raised Beach there.

In his classical paper on the Raised Beaches of the South of England, Sir Joseph Prestwich gave a diagram section of the brick-pit near Portslade Railway Station; ‡ and this agrees generally with the sections given below (see Figs. 1 and 4), which I took from the exposures in the sand-pits on the coast at Copperas§ Gap, within 36 yards of one another and almost due south of the Railway Station.

In these sections it will be seen that the thickness and general character of the Rubble-Drift vary considerably within short distances, owing to the Drift having been deposited in furrows running nearly due north and south, from the hills to the sea, a structure which can be well seen on reference to the 1-inch Drift map of the Geological Survey.

The manner of the deposition of these superficial beds upon the Chalk is shown in a section given by Prestwich,|| from the coast at Southwick to the Downs north of Portslade.

In the excavation in the sand of the cliff which I saw at Copperas Gap, the Chalk was not exposed, but it cannot be more than a few feet below the bottom of the pit, for it appears on the foreshore.

* "Fossils of the South Downs," Pls. IV and V. Also "Medals of Creation," 2nd ed. 1854, vol. ii, pp. 852-858.
† *Quart. Journ. Geol. Soc.*, vol. vii, p. 367.
‡ *Quart. Journ. Geol. Soc.*, vol. xlviii (1892), p. 270, Fig. 4.
§ In the 1-inch map spelt "Coppard's."
|| *Op. supra cit.*, Pl. VII, Fig. 2.

II.—The RAISED BEACH and its MICROSCOPICAL CONTENTS.

A. *The bed of White Sand.*

Commencing at the base of the sections exposed, a short distance to the east of Copperas Gap (Fig. 2), there is a thickness of about 12 to 16 ft. of fine whitish sand, with a few scattered flints, large and subangular. This bed of sand shows marked evidence of current-action, which increases towards the top. The uppermost 10 inches is of a ferruginous colour, and is inclined to become laminated. Throughout the white sand-bed, but more

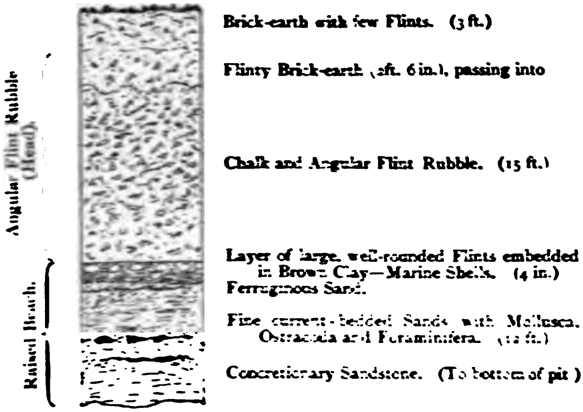


FIG. 1.—SECTION OF THE RAISED BEACH AND RUBBLE-DRIFT AT COPPERAS GAP.

especially towards the upper part, numerous shells are found disposed in narrow bands. They are chiefly of one species, *Littorina obtusata*, Gmelin. Numerous fragments of *Mytilus edulis*, L., and a small example of *Purpura lapillus*, L., were also found. One of the subangular flints, measuring 4½ × 3¼ inches, was encrusted with the barnacle, *Balanus crenatus*, Bruguière.

In parts of this sand-bed concretionary sandstone occurs along the plane of bedding, in pieces varying from an inch to three or four feet in length, and from the thickness of stout cardboard to about an inch: sometimes tabular, but often elongated and in grotesque tuberous shapes.* The percentage of carbonate of lime in a sample of this concretionary sandstone was found to be as much as 41·3. Where the shell layers are found the concretionary sandstone is rare or only in thin paper-

* Tabular and concretionary sandstone also occurs in the sand-pit at the S.E. corner of Goodwood Park, and in the Raised Beach at Hope's Nose, E. of Torquay; at both of these localities its origin may be due to the same conditions as those described above.

like seams; but where the sandstone-layers are best developed no shells are found. It may therefore be reasonably supposed that the shell-bands were the source of the $CaCO_3$ which forms the cement around the grains of the sandstone.

When we examine a thin section of this sandstone the grains are seen to consist mainly of sharply angular quartz, with a few rounded grains of the same mineral, and angular chips of flint in less proportion; some felspar and other mineral fragments, as

FIG. 2.—THE RAISED BEACH AND RUBBLE-DRIFT AT ALDRINGTON, NEAR BRIGHTON.

A. RUBBLE-DRIFT. B. RAISED BEACH.
a. SHINGLE BED. *b.* FERRUGINOUS SAND.
c. WHITE MARINE SAND WITH CONCRETIONS.

well as glauconite casts of foraminifera, and broken sponge-spicules, the two last being derived from the adjacent Chalk. The whole of the grains thus cemented together are separated from one another by an even area of calcite (see Fig. 3). It may be assumed that in its early stage this deposit of $CaCO_3$ around the grains was in the form of aragonite, and that this, the unstable form of carbonate of lime, has since passed into the fixed form of calcite. From this and many similar occurrences, such as the oolitic limestones with a crystalline groundmass, it is natural to suppose that the granules, although lying at first in contiguity with

one another, in the loose condition of sand, have been afterwards spaced out, as it were, by the insinuation of the concreting substance. Dr. C. G. Cullis, F.G.S., has also formed the same opinion regarding similar structures in the purely calcareous rocks forming the atoll of Funafuti.

The samples of sand taken for microscopical examination were obtained from the upper part of the bed, amongst the shell-layers with *Littorina*.

The assemblage of Ostracoda found here is remarkable for its mixed character. It comprises, besides some recent species of marine Ostracoda which naturally live near the shore-line, two species derived from the Wealden, seven species from the Chalk, and one from the Tertiary beds. In addition to these there are numerous well-preserved forms of recent Ostracoda which inhabit streams and pools at the present day; and which must have been transported to where they are now found, in the gentlest manner, seeing that, although so fragile, they are in many cases uninjured.

FIG. 3.—THIN SECTION OF CONCRETIONARY SANDSTONE FROM THE RAISED BEACH.

The *OSTRACODA* which I have found in the thick bed of sand of the Raised Beach near Portslade are as follows:

Species found inhabiting Streams, Ponds, and Marshes:

1. *Cyclocypris lævis* (Müller); rare.
2. „ *serena* (Koch); 1 specimen.
3. *Erpetocypris reptans* (Baird); 1 specimen.
4. *Prionocypris serrata* (Norman); fine specimens, fairly common.
5. *Ilyocypris gibba* (Ramdohr); frequent.
6. „ *bradyi*, G. O. Sars; rare.
7. *Candona candida* (Müller); rare.
8. *Limnicythere inopinata* (Baird): 1 specimen.

Marine Species indigenous to the RAISED BEACH. (Those marked N. are of northern habit.)

1. *Cythere villosa* (G O. Sars); frequent.
2. „ *lutea*, Müller; very common.
3. „ *concinna*, Jones; rare. N.
4. „ *angulata*, G. O. Sars; rare. N.

5. *Cythere finmarchica* (G. O. Sars); 1 specimen.
6. ,, *latissima* (Norman); rare.

Species derived from the Wealden:

1. *Cypridea tuberculata* (Sow.); 1 specimen.
2. ,, *valdensis* (Fitton).

Species derived from the Chalk:

1. *Bythocypris silicula* (Jones); 1 specimen.
2. *Bairdia subdeltoidea* (Münster); 1 specimen.
3. *Cythereis ornatissima* (Reuss), var. *nuda*, J. and H.; 1 specimen.
4. *Cytheropteron concentricum* (Reuss); 1 specimen.
5. *Cytherella obovata*, Jones and Hinde; rare.
6. ,, *muensteri* (Römer); 1 specimen.
7. ,, *ovata* (Römer); 1 specimen.

Species derived from Tertiary Beds [? Woolwich and Reading Series]:

1. *Cytheridea muelleri* (Münster); 1 good specimen.

The *FORAMINIFERA* found in the sands of the Raised Beach are also of a mixed character, being both derived and indigenous. The derived species are all more or less well-known Chalk and Gault forms, and the indigenous species are similar to those found on fine sandy shallow bottoms around our coast at the present day.

The Species of *FORAMINIFERA* presumably contemporaneous with the Raised Beach are as follows:

1. *Gaudryina pupoides*, d'Orb.; rare.
2. *Truncatulina lobatula* (W. and J.); rare.
3. *Pulvinulina exigua*, Brady; 1 specimen.
4. *Rotalia beccarii* (L.); frequent.
5. *Nonionina asterizans* (F. and M.); 1 specimen.
6. ,, *boueana*, d'Orb.; 1 specimen.
7. *Polystomella striatopunctata* (F. and M.); very abundant.
8. ,, *macella* (F. and M.); frequent.

The derived *FORAMINIFERA*, apparently from the Chalk and Gault, are as follows:

1. *Haplophragmium nonioninoides*, Reuss; 1 specimen.
2. ,, *agglutinans* (d'Orb.); 1 specimen.
3. *Ammodiscus incertus* (d'Orb.); 1 specimen.
4. *Gaudryina dispansa*, Chapman; 1 specimen.
5. *Bulimina affinis*, d'Orb.; 1 specimen.
6. ,, *variabilis*, d'Orb.; rare, large specimens.
7. ,, *brevis*, d'Orb.; rare.
8. *Bolivina strigillata*, Chapman; rare.
9. *Pleurostomella obtusa*, Berthelin; 1 specimen.
10. *Frondicularia archiaciana*, d'Orb.; a fragment.
11. *Flabellina rugosa*, d'Orb.; 1 specimen.
12. *Cristellaria scitula*, Berthelin; 1 specimen.

13. *Cristellaria cultrata* (Montf.); rare.
14. *Globigerina marginata* (Reuss); frequent.
15. *Truncatulina ungeriana* (d'Orb.); frequent.
16. „ *refulgens* (Montf.); rare.
17. *Anomalina ammonoides* (Reuss); common.
18. *Pulvinulina elegans* (d'Orb.); 1 specimen.
19. „ *haidingerii* (d'Orb.); rare.
20. „ *micheliniana* (d'Orb.); common.
21. *Rotalia exsculpta*, Reuss; common.
22. „ *soldanii*, d'Orb.; 1 specimen.

The presence of the derived Chalk Ostracoda and Foraminifera is easily accounted for, since they are obviously the result of the disintegration of the Chalk beds which constituted the cliffs at the time of the formation of the Raised Beach. The freshwater species of Ostracoda were in all probability carried down by the streams which drained the more or less flat surfaces near the coast, and it is worth the consideration whether these remains of freshwater Ostracoda do not point to the former existence of outliers of Lower Tertiary beds, which, being impervious, would furnish the requisite conditions of a wet and marshy subsoil. That such a superficial bed did formerly exist here about the period of the formation of the Raised Beach is highly probable from corresponding evidence elsewhere along the South Coast, and especially so with regard to the overlying Rubble Drift. Should this not have been the case it would be difficult to understand the presence of marsh-loving species, which occur in such frequency, where, at the present time, there is little impervious material resting on the Chalk.*

Another somewhat difficult problem meets us in the presence of two species of Wealden Ostracoda in the Raised Beach deposit. The nearest outcrop of the Wealden beds at the present time is in Pevensey Bay; but it is more probable that the minute carapaces mentioned may have been brought down by a river draining the Weald, such as the river Adur, debouching at Kingston-by-Sea,† or the river Ouse at Newhaven.

The Tertiary species of *Cytheridea* was most likely derived from an outlier of the Lower Tertiaries.

It is interesting to note in relation to the derivation of the introduced species of the Raised Beach, that Prof. Prestwich refers‡ in a similar way to the presence of fragments of the fossiliferous Middle-Purbeck rocks in the Head or Rubble-Drift of Portland Bill. These rocks are not now found *in situ* on the Island. Similarly, these fragile fossils are here preserved as remnants of pre-existent strata.

* A similar case is that of the occurrence of land and marsh shells with Ostracoda such as *Scottia browniana* and *Candona candida* in the Rubble at Chesilton, about which Prof. Prestwich has remarked "There may have been a piece of marshy ground or a pond in the Kimeridge Clay here, previously." *Quart. Journ. Geol Soc.*, vol. xlviii (1892), p. 278.

† The River Adur within recent knowledge flowed out at a point nearly opposite Portslade-by-Sea.

‡ *Quart. Journ. Geol. Soc.*, vol. xxxi (1875), p. 36.

The area in which this sand-bed of the Raised Beach was laid down may have been slowly subsiding and filling up, since the condition of the deposit remains the same throughout, and the shells are littoral species.

B. *Topmost bed of* RAISED BEACH, *with Shingle layer.*

The uppermost four inches or so of the Raised Beach between Hove and Portslade differs much in character from the underlying stratum, and will here be considered separately. It consists of a layer of large, well-rounded flint pebbles, often measuring three or four inches in their longest diameter, embedded in a rich brown sandy clay. One notices, when picking these pebbles out of the clay, that they are resting directly on a shell-bed, and fragments of the shells adhere to the under surfaces of the pebbles. The greater part of the shells forming this layer are *Mytilus edulis*; and *Cardium edule* is occasionally found with them.* The shells of *Mytilus* found here are extremely fragile, and it is next to an impossibility to extract them entire. The reason of this is owing to the partial dissolution of the shell. In *Mytilus* the shell consists of an inner layer of aragonite which readily dissolves, and an outer layer of the more stable calcite. In the present case only the outer shell-layer remains; and since this is of a granular texture, the shell is extremely friable. A similar case was pointed out by Dr. Sorby in his most perspicuous address to the Geological Society in 1879,† when he described a like condition of the shell of *Mytilus* in the Raised Beach at Hope's Nose, Torquay.‡

The brown clay, when washed, yields a residuum of dark-brown sand containing a large proportion of the heavier minerals; and amongst these I have detected four which are often found in fine arenaceous clays. They are zircon, very abundant, some sharply crystalline, others with the edges of the crystal rounded, and with numerous inclusions; also tourmaline, rutile, and kyanite.

The washings from the brown clay also contained, in the lighter portion, many species of Foraminifera and one Ostracod. No derived forms were found in this layer, although they are so common in the beds immediately below and above. This clearly shows that during this stage of deposition there was an entire cessation of the fluviatile influences which previously brought down Cretaceous microzoa and living freshwater Ostracoda from the land behind. The Foraminifera are all very minute, with the exception of *Polystomella striatopunctata*. The solitary valve of the *Cythere* found here is very thin and partially dissolved, so that the superficial puncta are marked by distinct perforations.

* I am indebted to the Misses Constable, of Portslade, for much help in obtaining mollusca from the Raised Beach.

† *Quart. Journ. Geol. Soc.*, vol. xxxv (1879), p. 65.

‡ Mr. A. Bell, who has examined the mollusca for me, writes that "this fragile condition of the *Mytilus* shell is not common, and I have only previously met with it at Shoreham and a few other localities."

Contemporaneous *OSTRACOD* from the Brown Clay, *top* of RAISED BEACH.

Cythere lutea, Müller.

Contemporaneous *FORAMINIFERA* from the same bed.

1. *Bulimina elegantissima*, d'Orb.; 1 specimen.
2. *Bolivina punctata*, d'Orb.; 1 specimen.
3. „ *dilatata*, Reuss; 1 specimen.
4. „ *plicata*, Reuss; common.
5. „ *textilarioides*, Reuss; frequent.
6. *Uvigerina angulosa*, Williamson; 1 specimen.
7. *Patellina corrugata*, Will.; 1 specimen
8. *Discorbina globularis* (d.'Orb.); 1 specimen.
9. „ *rugosa* (d'Orb.); 1 specimen.
10. *Truncatulina ungeriana* (d'Orb.); rare.
11. „ *lobatula* (W. and J.); rare.
12. *Pulvinulina repanda* (F. and M.), var. *concamerata* (Montagu); rare.
13. *Rotalia beccarii* (Linné); 1 specimen.
14. *Nonionina boueana*, d'Orb.; common.
15. *Polystomella striatopunctata* (F. and M.); very common.

From the evidence of the included shells, this bed indicates slightly deeper water conditions than the bed of sand previously described, and was probably deposited at such a depth as to be always below the lowest tide. The rolled pebbles may have been moved to their present resting-place on the mussel bed by a sudden change in the set of the currents.

III.—THE HEAD OR RUBBLE-DRIFT.

The thickness of the Head at Portslade and Hove, and indeed wherever met with, is extremely variable. Within a few yards, as will be seen by comparing Figs. 1 and 4, there is a difference of 6 ft. At Portslade it is almost uniformly composed of angular flints embedded in a loose, chalky matrix. For comparison, we may notice that the Elephant-bed to the east of Brighton, which is a local development of the Rubble-Drift, contains less flinty material in the upper part, and in some places appears as a loose, chalky sand of a whitish or yellowish-brown colour; it is largely composed of small chalk pebbles of every gradation in size, from minute grains up to pebbles many inches in diameter. At Copperas Gap, between Hove and Portslade, one of the cliff-sections shows a variation in the nature of the Rubble-Drift, where a lenticular seam of fine, chalky material occurs, strongly flexed or even contorted, such as would lead one to ascribe its origin to ice- or frost-action. The material of which it is composed, consists of a nearly pure foraminiferal sand, derived from the Chalk, and is comparable in many respects with

the Elephant-bed at Black Rock. This seam is very different from the enclosing drift, which is a coarse rubble of angular flint and chalk. When a portion of this finer rock was dropped into a vessel of water, it immediately crumbled down into a fine powder with a few chalk pebbles and a little suspended material. The fine sandy residue consisting of Chalk foraminifera is in such a clean condition as would be almost impossible to obtain by mechanical means when treating ordinary fresh chalk for the purpose of extracting the shells. To account for this perfect disintegration of the rock, it can hardly be ascribed to any other agency than that of an alternation of frost and thaw. The "chalk detritus" of Charing, in Kent, which is found at the foot of the

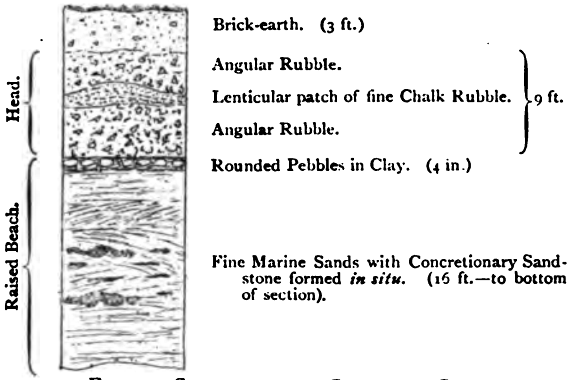


FIG. 4.—SECTION NEAR COPPERAS GAP.

hills, and which has yielded such a rich harvest of microzoa in the hands of specialists, may also be due to this particular action of weathering.

To give a fairly adequate idea of the abundance of microzoa contained in this chalky seam in the Rubble-Drift, I append the following lists, the result of a not very exhaustive examination of the washings. In the sequel, the names of those species are indicated which were found in a sample of the Elephant-bed of Black Rock, collected for me by Miss Constable.

OSTRACODA from a lenticular chalky Seam in the RUBBLE-DRIFT near PORTSLADE.

CRETACEOUS SPP.

1. *Cythereis spinicaudata*, Jones and Hinde.
2. „ *lonsdaleana*, Jones.
3. „ *ornatissima* (Reuss), var. *stricta*, J. and H.
4. *Cytheridea perforata* (Römer).
5. *Cytheropteron concentricum* (Reuss).
6. „ *umbonatum* (Will.), var. *acanthoptera* (Marsson).

7. *Cytherella ovata* (Römer).
8. „ *obovata*, Jones and Hinde.
9. „ *muensteri* (Römer).
10. „ *williamsoniana*, Jones.

A Recent Freshwater or Brackishwater Form.

11. *Cypria lævis* (O. F. Müller).

FORAMINIFERA from a lenticular chalky Seam in the Rubble-Drift near Portslade.

1. *Textularia globulosa*, Ehrenberg.
2. „ *trochus*, d'Orb.
3. „ *conica*, d'Orb.
4. *Spiroplecta prælonga* (Reuss).
5. *Verneuilina spinulosa*, Reuss.
6. *Bulimina affinis*, d'Orb.
7. „ *pupoides*, d'Orb.
8. „ *murchisoniana*, d'Orb.
9. „ *brevis*, d'Orb.
10. „ *presli*, Reuss.
11. *Bolivina decorata*, Jones.
12. *Lagena striata* (d'Orb.).
13. *Nodosaria tenuicosta*, Reuss.
14. „ *obscura*, Reuss.
15. *Frondicularia angulosa*, d'Orb.
16. *Rhabdogonium tricarinatum* (d'Orb.).
17. *Marginulina elongata*, d'Orb.
18. *Flabellina rugosa*, d'Orb.
19. *Cristellaria navicula*, d'Orb.
20. „ *triangularis*, d'Orb.
21. „ *planiuscula*, Reuss.
22. „ *lituola*, Reuss.
23. „ *gaudryana*, d'Orb.
24. „ *convergens*, Born.
25. „ *rotulata* (Lam.).
26. „ *subalata*, Reuss.
27. *Ramulina aculeata*, Wright.
28. *Globigerina marginata* (Reuss).
29. *Truncatulina lobatula* (W. and J.).
30. „ „ var. *variabilis*, d'Orb.
31. „ *ungeriana* (d'Orb.).
32. „ *akneriana* (d'Orb.).
33. *Anomalina rudis* (Reuss).
34. „ *ammonoides* (Reuss).
35. „ *complanata*, Reuss.
36. *Pulvinulina haidingerii* (d'Orb.).
37. „ *micheliniana* (d'Orb.).
38. „ *karsteni*, Reuss.

39. *Rotalia exsculpta*, Reuss.
40. „ *soldanii* (d'Orb.), var. *nitida*, Reuss.

Derived Chalk *FORAMINIFERA* from the ELEPHANT-BED (Rubble-Drift) at BLACK ROCK, near BRIGHTON.

1. *Verneuilina spinulosa*, Reuss.
2. *Bulimina brevis*, d'Orb.
3. *Anomalina ammonoides* (Reuss).
4. *Pulvinulina micheliniana* (d'Orb.).
5. „ *elegans* (d'Orb.).
6. *Rotalia exsculpta*, Reuss.

Prof. Prestwich, in accounting for the formation of the "Head," does not admit the agency of ice-action in so recent a deposit as this, yet, notwithstanding the clear and strong evidence which that eminent writer has given us in favour of the theory of submergence, elevation, and disintegration of the prominent land-surfaces by the strong current-action due to the emergence of the land, it seems apparent from the evidence given above, that severe frosts acted, now and again, in a very marked way, concomitantly with the aqueous denudation.

From the investigations of Mr. Clement Reid * and Mr. Lewis Abbott† we have no doubt of the existence of shore-ice and severe frosts at the time of the deposition of the "Mud Deposit" of Selsey, and of the Raised Beaches, and it is not unreasonable to suppose that these conditions recurred at intervals during the formation of at least the earlier part of the Rubble-Drift.

[After completing the foregoing paper on the Aldrington Raised Beach and Head, my attention was called to a paper by Mr. S. H. Warren‡ on the same section at Aldrington, which I had overlooked. Mr. Warren gives the following section, which generally accords with that given in the present paper:

"4. Surface Soil	1 ft.
3. Dark-coloured, stony clay, descending into pipes	6 in. to 3 ft. or more.
2. Contorted chalky loam, a large proportion of its mass being composed of flints, often broken, and said to yield mammalian remains at the base ...	10 to 12 ft.
1. Light-coloured sand, red in the upper part, with layers of well-rolled flint-pebbles, and many concretionary nodules, which are sometimes tubular. Marine mollusca and Balanidæ fairly abundant. *Mytilus edulis* in the pebbly layer. *Natica* [Littorina obtusata], etc., in the sand. Seen to	9 ft."

It is also interesting to note that Mr. Warren remarks on the peculiar contortion of parts of the Rubble-Drift at this spot, and suggests the probability of grounded ice having been the cause of the phenomenon.]

* *Quart. Journ. Geol. Soc.*, vol. xlviii (1892), p. 347 *et seq.*
† *Op. cit.* p. 269, footnote.
‡ "Note on a section of the Pleistocene Rubble-Drift near Portslade, Sussex." *Geol. Mag.*, 1897, pp. 302-304.

THE PLEISTOCENE DEPOSITS OF THE ILFORD AND WANSTEAD DISTRICT.

By Martin A. C. Hinton.

(*Read June 2nd*, 1899.)

SINCE 1838, when Prof. Morris wrote a description of the Ilford beds,* much has been written on the Drift of the district. A review of the literature of the Thames Valley Drift was published in the *Memoirs of the Geological Survey* ("The Geology of London," vol. i, 1889, pp. 353-387).

A series of papers, in part relating to the Thames Valley, was published in the *Geological Magazine* during 1872 by Prof. James Geikie.† In my opinion his conclusions are incontestable, in so far as they relate to the Palæolithic era, and have never been satisfactorily answered by those holding contrary views.

Another paper to which I shall specially refer is that by Messrs. Kennard and B. B. Woodward, "On the Post-Pliocene non-marine Mollusca of Essex," ‡ in which a complete list of the Ilford shells is given.

High-Terrace Drift.

Wanstead.

Of this patch, extending from Leytonstone to Wanstead, only the south-eastern corner lies within our district. In a small gravel-pit, about a furlong north-west of Wanstead Park, and at a height of about 80 ft. O.D., some interesting sections have been noted.

In the western face of the pit may be seen beds of bleached pebbles and shingly gravel, probably indications of old land-surfaces, such as might be formed by the level of the river falling during dry seasons. In March, 1898, the following section was exposed on the northern side of this pit:

1. Stratified gravel	1-2 ft.
2. Contorted and lenticular beds of sand	1-2 ft.
3. Gravel, much contorted	4-5 ft.
4. Seams of sand, bluish clay, marl, and gravel, very much contorted	1-4 ft.
5. Gravel slightly contorted...	2-5 ft.

This section shows that the contorted and disturbed material is overlain by undisturbed gravel. The overlying gravel is undoubtedly Pleistocene, and, in my opinion, proves the age of the disturbance. The contortion was possibly caused by the grounding and partial melting of a large ice-raft on a shoal in

* Prof. John Morris, "On the Deposits containing Carnivora and other Mammalia in the Valley of the Thames." *Ann. Mag. Nat. Hist.*, Ser. II, vol. ii, 1838, pp. 539-548.

† Afterwards incorporated in "The Great Ice-Age," 1874, pp. 431-503.

‡ *Essex Naturalist*, vol. x, 1897, pp. 87-109.

the stream. The fact of its having partly melted, or at least of the deposition of part of its detritus, is shown by the seams of marl and of a blue clay, which resembles ordinary boulder clay both in tenacity and constitution. The ice, thus relieved of its burden, gradually floated away. This phenomenon would only occur in a district subject to a severe climate, and the evidence to be noted below supports this view.

Last October, I found a seam of the dioxide of manganese in this pit at a depth of about 12 ft.,* and associated with it was a portion of a skeleton of *Equus caballus*, the only fossil found. Flint implements are rare in this pit, and only a few small flakes were found, but elsewhere in this patch of Drift they have been met with in abundance.

Barkingside.

On the left bank of the river Roding are two patches of High-Terrace Drift. That furthest south shows no section, with the exception of a few ditch exposures, but its boundary may be easily traced. The other is much larger, and only the western portion lies within our district. At St. Swithin's Gravel pit (90 ft. O.D.) occurs a gravel, overlying sand, similar to that at Wanstead, but without contortion. "Trail" is often well developed in this pit. Mr. Crouch mentions that the gravel here is sometimes slightly faulted, which may be due to slipping. Loam is seen capping the gravel in the pit and also in a road-cutting near by. This loam has not been noted by the Geological Survey. I obtained a considerable number of bones of a small *Bos primigenius* or *Bison priscus*. I have also found several palæolithic flint-flakes and implements. Mr. Hatton, the late proprietor, informed me that teeth of ox and of horse have been found.

These High-Terrace gravels contain an abundance of large, smooth, and apparently ice-worn foreign rocks, fragments of Triassic sandstones, Lickey and other quartzites, and of sarsen-stones, which have not been subjected to any great amount of water-action. Among the other foreign materials are large boulders of Carboniferous chert, of gneiss, and occasionally mica-schist. The presence of these large boulders may be due to the transporting power of masses of ice, acting upon a river-bank containing moraine matter. Many of the quartz and flint-pebbles are also of large size. The smaller material consists chiefly of flint and quartz with a few Triassic sandstone pebbles.

Dr. Corner possesses a flint implement found in Middle-Terrace gravel, but evidently derived from High-Terrace Drift, as shown by its abraded condition, which bears distinct ice-striæ on its *fractured surfaces.*

* Martin A. C. Hinton, "On Manganese in River Gravels." *Science Gossip*, vol. vi, 1899, New Series, pp. 146, 147.

MIDDLE OR LOW-TERRACE DEPOSITS.

Great Ilford.

The deposits of Great Ilford form part of a sheet of Drift which extends from the left bank of the river Roding to near Hornchurch. Of this great sheet, only the western portion lies within the district under discussion: but as this portion includes the Brickearths it is of much interest. The principal sections are situated at a height of 44 ft. O.D., on the northern side of the railway and on the left-hand side of the footpath which leads to the iron foot-bridge, in a pit known locally as the "Sam's Green," "Cauliflower," or "Page's" pit. The sections exposed are of great extent and have yielded a large number of fossils, including the greater part of Dr. Corner's collection and the whole of my own. The sections vary from time to time as the pit is gradually worked towards the north. In 1897 the following section was exposed on the northern side:

a. Gravel (Trail)	2 ft.
b. { b^1 Dark brown brickearth with shells ...	
b. { b^2 Light brown brickearth with shells ...	15 ft.
c. Very sandy loam with bones and shells ...	
d. Sand	6 ft.

This section was chiefly remarkable on account of the number of well preserved mammalian remains exhumed. In the winter of 1897-8, the workmen came upon a portion of a skeleton of *Elephas primigenius*, with one of the tusks almost complete; but the only specimen obtained, was a small upper molar tooth with the crowns but little worn.

The following section on the northern side of the pit was noted by me on the 30th May, 1898:

a. Gravel and loam (Trail), the pebbles nearly all having their long axes vertical	2-7 ft.
b. Brown loam	4-9 ft.
c. Buff loam	3 ft.
d. Sand, seen to	4 ft.

This section is remarkable for the great development of the "Trail." The underlying bed is much contorted.

The best section is on the western side of the pit. It differs very little from year to year, and Dr. Corner informs me that in 1898 it was practically the same as in 1893. The following beds are seen:

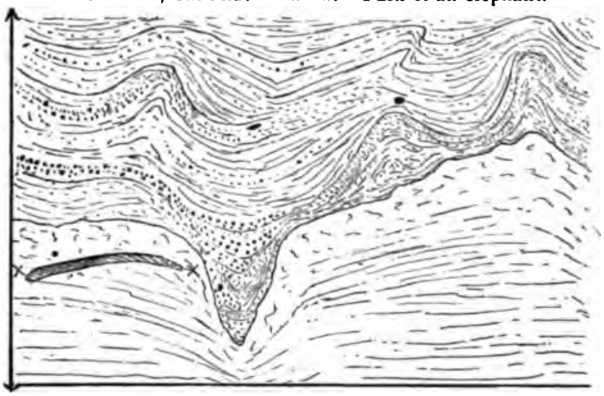
a. Gravel and loam (Trail), very well marked in places	1-4 ft.
b. { Sandy loam, more argillaceous in places	1-4 ft.
Shell-bed, inconstant, containing numerous shells, also bones of *Bos primigenius*	9in.-1 ft.
Sandy loam	4 ft.
Shell-bed, resting on the eroded surface of Bed *c*	6in.-1 ft.
c. Buff-coloured loam and marl, with race; somewhat sandy (Bone-bed)	1-5 ft.
d. White sand with a few shells	5 ft.
A well sunk in 1897 passed through sand and gravel	30 ft.

Dr. Cotton* noted a similar development of Drift occurring S.W. of Uphall. That this great development is influenced by the presence or absence of the underlying gravel is shown by the fact that between the two places the brickearth attains a thickness of about 20 ft., and that it rests directly upon the London Clay.† Hence the Ilford gravel must lie in hollows or old channels of erosion in the London Clay. Since it is extremely likely that these hollows would be the first portion filled up when the deposition of the gravel and sand commenced, it is probable that the gravel and sand of Ilford form the oldest part of the Middle or Lower Terrace Drifts of the district.

The large section on the western side of the pit differed somewhat in 1899. In 1898 and the preceding years, the "Bone-bed" was observed to overlie the sand. On cutting back the sand (in 1899), it was seen that the "Bone-bed" became more sandy, and finally developed into an interstratified series of sand and marl, dipping to the north at an angle of 10 deg. Only the lower shell-bed was to be seen, and towards the south it thinned out altogether.

FIG. 1.—SECTION OF CONTORTED DRIFT IN THE CAULIFLOWER BRICKYARD, ILFORD. *x—x*. Tusk of an elephant.

11 feet.



The finest examples of Trail that I have noted at Ilford were exposed in this pit in the spring of 1899. On the western side, some of the furrows were over 8 ft. in depth, and filled with gravel and sand. The gravel consists of beds of flint- and quartz-pebbles (mostly with their long axes vertical) and of thin layers of sub-angular shingly flint and quartz material, the fragments lying in all positions. At one point, just below where the "Trail" commenced to cut down into the loam, a portion of an elephant's

* Dr. R. P. Cotton, "On the Pliocene Deposits of the Valley of the Thames at Ilford." *Ann. Mag. Nat. Hist.*, vol. xx, 1847, pp. 164-9.

† S. V. Wood, Junr., "On the Structure of the Thames Valley, and of its contained Deposits." *Geol. Mag.*, vol. iii, 1866, pp. 57-63, 99-107.

tusk, crushed into small fragments, was seen (Fig. 1). On the eastern side, an even finer section of the contorted Drift was seen (Fig. 2). This exhibited several furrows, varying from 8 to 9 ft. in depth, and filled with similar *débris* to that occurring in the other parts of the pit. The contorted loam was in places forced up into long thin necks, projecting into the furrows. This, with the crushed tusk mentioned above, may be taken as evidence of the crushing action of ice.

FIG. 2.—SECTION OF CONTORTED DRIFT IN THE CAULIFLOWER BRICKYARD, ILFORD.

1. Gravel and Sand of Trail.
2. Contorted loam, torn up into necks at *x*.
3. Sand (much indurated) false bedded in places.

In March, 1893, Dr. Corner discovered a flint flake or knife in the lowest shell-bed of the western section of the pit, and this year he has found another in the same place. So far as we are aware, these are the first traces of human work known from the brickearth at Ilford.

The section exposed on the northern side of the pit in 1899 was as follows:

a.	Gravel. sand, and clay (Trail)	3-4 ft.
b.	Sandy loam, contorted in its upper part... ...	4-6 ft.
c.	Brown loam with mammalian bones and teeth, about	6 ft.

The suncracks that occur in the beds form an interesting feature occasionally to be seen in this pit. They consist of vertical fissures filled with sand, which is often cemented into a hard mass by iron-oxides. They are of two distinct ages, Pleistocene and Recent, and may be distinguished by the following characteristics: Those of Recent age are the more abundant, and invariably reach the surface. Many of them are formed each summer after the surface soil is removed. The

infilling material, when present, is seldom consolidated. So numerous are these fissures, that, in the upper portion of the beds, it is a matter of great rarity to find any of the abundant mammalian remains unbroken by them. On the other hand the Pleistocene suncracks may be regarded as those not reaching the surface, and always filled with material which is more or less consolidated by oxides of iron, and occasionally by the black di-oxide of manganese. These Pleistocene suncracks in the beds of loam, are to be explained by the action of the heat of the sun acting upon mud-banks when the river was low, causing the mud to contract and form fissures, which, when the river again rose, became filled with detritus and were ultimately covered with fresh deposits of loam or other material.

In August, 1898, I noted a section in the old pit on the right-hand side of the footpath leading to the iron footbridge, which is one of three described by Prof. Morris in 1838. It has been abandoned now for several years, but I was able to make out the following details:

a.	Gravel and sand ("Trail")	3-4 ft.
b.	Brown loam, bottom part much obscured ...	4 ft.
b. (?)	Pebbly loam	4-6 ft.
c.	Thin layers of sand and clay with fragments of shells	4 ft.

The beds lettered "*c*" appear to be very constant at Ilford, sometimes in the form of buff loam, and sometimes as above. In some places bones are extremely abundant, the layer being termed the "Bone-bed" by the workmen. Wherever this bed is argillaceous, it is also very calcareous and full of large nodules of "race."

Westward of the River Roding.

From Great Ilford towards Manor Park the Drift becomes thinner, being nowhere more than 20 ft. in thickness, and generally much less, as the following sections will show:

Excavations for houses in Carlyle Road, Manor Park:

1.	Gravel and sand with a Palæolithic flake ...	6-8 ft.
2	Sand with bones of *Equus caballus* and *Bos primigenius*	12-14 ft.
	London Clay throwing out water at a depth of	20 ft.

Further east in the same road was seen:

1.	Gravel with thin seams of sand	4-5 ft.
2.	Sand	10 ft.
	London Clay throwing out water at a depth of	15 ft.

At the City of London Cemetery the gravel is in places only 8 or 9 ft. in thickness, and London Clay is to be seen at the bottom of many of the graves. Flint implements are very abundant in the gravel.

LIST OF VERTEBRATA FROM ILFORD.

	Uphall pit	Cauliflower pit
MAMMALIA.		
Homo (implements)	×	×
Canis lupus, Linn.	×	×
Canis vulpes, Linn.	×	
Felis leo, Linn.	×	
Ursus arctos, Linn.	×	×
Ursus ferox, Richd.	×	×
Bison bonasus, Linn. var. *priscus*, Boj.	×	×
Bos taurus, Linn. var. *primigenius*, Boj.	×	×
Cervus elaphus, Linn.	×	×
Cervus giganteus, Blum.	×	×
Capreolus caprea, Gray	×	×
Elephas antiquus, Falc.	×	×
Elephas primigenius, Blum.	×	×
Equus caballus, Linn.	×	×
Hippopotamus amphibius, Linn.	×	
Ovis ?	?	
Rhinoceros antiquitatis, Blum.	×	
Rhinoceros leptorhinus, Owen	×	×
Rhinoceros megarhinus, Christ.	×	×
RODENTIA.		
Microtus (Arvicola) amphibius, Linn.	×	×
Microtus (Arvicola) arvalis ?, Pall.		×
Castor fiber, Linn.	×	
AVES.		
Anas sp.	×	×
Anser sp.	×	
Diomedia exulans, Linn.	×	
PISCES.		
Esox lucius, Linn.	×	

NOTES ON THE VERTEBRATA.

CARNIVORA.—Among the carnivora found fossil at Ilford, *Canis* is the most abundant. Dr. Corner possesses a fine skull of *Canis lupus* from the "Trail," which I regard as a genuine Pleistocene fossil. The remains of *Ursus* are rare. Rarest of all is *Felis*.

UNGULATA.—The more abundant species are *Bos primigenius* and *Bison priscus*. It is the general rule to refer bovine bones to the former species as it is not generally deemed safe to venture to distinguish between them, except in cases where the skull and horn-cores are preserved. On this account the abundance of *Bos primigenius* may be somewhat exaggerated.

Cervus elaphus is the common form of deer found at Ilford,

but *Cervus megaceros* is extremely rare. *Cervus tarandus* is unknown from any Pleistocene deposit in the Thames Valley below London, although it has been found in the Holocene of Walthamstow.

Equus caballus is fairly common, and is generally of medium size. Of the specimen from the High-Terrace Drift of Wanstead, exhibited at the Conversazione of the Association in 1898, the rudimentary metacarpal and metatarsal bones were of large size. Besides these, a case of unequal ossification of the tarsal bones of both legs was exhibited.

Elephas primigenius is the common form and in addition a peculiar variety occurs.*

Rhinoceros leptorhinus occurs in great number, *R. megarhinus* is fairly abundant, but remains of *R. antiquitatis* are very rare, and have not been recorded from the Cauliflower brickyard.

RODENTIA.—*Castor fiber.* A very fine series of bones of *C. fiber*, obtained from Uphall, is preserved in the Museum of Practical Geology (Cotton Collection). *Microtus* (*Arvicola*) *amphibius*, the water vole, is also recorded from Uphall, and specimens are in the Cotton Collection.

These two species were the only small Rodentia known from Ilford until 1898, when I discovered in the Cauliflower Pit a small cheek-tooth and portion of a femur. The cheek-tooth Mr. Newton has identified as the second right upper molar of *Microtus* (*Arvicola*) *amphibius*—a species already known from Uphall. The femur, however, supplies us with a new record for Ilford. Mr. Newton says that, from its size, it is referable to a small field vole, and corresponds most nearly with *Microtus* (*Arvicola*) *arvalis.* These specimens indicate a possible source from which more of these small vertebrates may be obtained.

AVES.—Portion of an ulna of *Anas* sp. is preserved in the Museum of Practical Geology (Cotton Coll.) from Ilford, and there is also a fragment in Dr. Corner's collection. These are the only specimens known from the Thames Valley Drift. *Anser* sp. is represented by a portion of an ulna, in the Cotton Coll. The specimen is the only one known from Ilford, but the species occurs at Crayford. A left ulna of *Diomedia exulans*, from Ilford, is preserved in the Museum of Practical Geology. There is some doubt as to this being a Pleistocene fossil, but its general appearance is not unlike that of many of the bones obtained at the Cauliflower pit. I am of opinion that it is a genuine Pleistocene fossil.

PISCES.—The sole representative of the fishes is *Esox lucius*, the pike, preserved in the British Museum (Brady Coll.).

* W. A. Davies, "On a Variety of *Elephas primigenius* from Ilford," "Cat. Pleist. Vertebrata in the Brady Collection." 1874. P. 4. See also E. T. Newton's "Vertebrata of the Forest Bed." *Mem. Geol. Surv.*, 1882, p. 106.

It will thus be seen that twenty-six vertebrates occur at Ilford, of which twenty-five are known from Uphall and seventeen from the Cauliflower pit. Of these vertebrates, twenty-two are mammals, three are birds, and one a fish.

Conclusions.

The High-Level Drift of the Ilford and Wanstead district, as we have seen, gives strong evidence of the rigorous nature of the climate during the earlier part of the Palæolithic period. At Wanstead there is unmistakable evidence of the rivers having been frozen in winter; and, on the breaking up of the ice, of huge ice-rafts floating down, contorting the deposits in process of formation wherever they grounded, and depositing their burdens of detritus. Similar occurrences were brought to the notice of the Association by Mr. Allen Brown when dealing with the High Terrace Drift of Acton and Ealing.* The antiquity of these disturbances admits of no argument, for in the cases above mentioned they have been overlain by Pleistocene deposits. Furthermore, they are on a scale that is never attained by the ordinary surface-derangements, and more particularly was this the case in the occurrences noted by Mr. Allen Brown.

In the fauna of the High-Terrace Drifts of the Thames Valley, we find that, among the Mollusca,† there is but one record of a southern shell occurring in these deposits, viz., *Corbicula fluminalis* from Dartford Brent. It does not follow, however, that because *Corbicula fluminalis* has now a southern range it indicates a warm climate. It must be noted that this form occurs in the Red and Norwich Crags and in the inter-glacial beds of Kelsea. The latter beds I take to be equivalent in age to the earlier Palæolithic deposits, and as they contain, besides *Corbicula fluminalis*, the marine shells *Cyprina islandica* and *Tellina balthica*, in all probability it could withstand a cold climate. The other shells are of a northern facies, or, at least, could have withstood a cold climate.

Of the Mammalia we find only such forms as the ox, horse, mammoth, and woolly rhinoceros.

But when we examine the fauna of the Lower-Terrace brick-earths we find that instead of the scanty species and numbers of the High-Terrace Drift we have evidence of an extremely rich fauna. The herbivorous Mammalia include the southern forms, such as hippopotamus, rhinoceros, and elephant, while of the Carnivora, lion and hyæna occur.

With regard to the Mollusca, a similar contrast is exhibited

* J. Allen Brown, "Notes on the High-Level Drift between Hanwell and Iver." *Proc. Geol. Assoc.*, vol. xiv, 1895, p. 153.

† B. B. Woodward, "On the Pleistocene (Non-marine) Mollusca of the London District." *Proc. Geol. Assoc.*, vol. xi, 1890, pp. 335-388.

between the present and the Palæolithic faunas. The Pleistocene molluscan fauna, as represented in the fossiliferous brick-earths, is admitted to be richer than that now existing. Though many of the species range from North Africa to the North of Europe, still, seeing that they attain their maximum development, as a whole, in the warm southern regions of Europe to-day, is it not reasonable to assume that their great Pleistocene development took place during a period in which the climate was as genial as it is in these islands at the present time? Numerous specimens of *Littorina rudis* have been found in the brick-earth at Crayford, and *Paludestrina ventrosa* is known from Crayford, Ilford, and Grays. The examples of *Littorina rudis* are all dwarfed and are exactly similar to a form living at Tilbury, while *Paludestrina ventrosa* is a well-known brackish-water shell. A record by Prof. Seeley of *Scrobicularia piperata* from the Ilford brickearth * led to an inquiry as to the correctness of its occurrence. Prof. Seeley very kindly gave me the following information in reply. He says:

"*Scrobicularia* was found, and the determination is given on my authority from specimens shown me in the pit at Ilford. They were rather small. I did not take any myself. . . . I will see if any specimens can be traced. My impression is that two or three entire and one or two broken valves were found. . . . The Ilford occurrence of *Scrobicularia* is interesting to anyone who has studied its distribution and variation on the mudflats of brackish water inlets on the Coast of Suffolk, where it may be found side by side with freshwater shells."

In 1872 the Rev. O. Fisher suggested that at the time the Crayford brickearths were deposited "The Thames could hardly have been a tributary of the Rhine, but must have possessed an estuary of its own as at present, and probably the tide came even higher up than it does now."†

Mr. Whitaker, however, did not agree with this view, and stated that "There is nothing in the fossils to show the presence of this tidal action."‡ The presence of these marine and estuarine forms, however, lends great support to the Rev. O. Fisher's views.

When we examine the lithological character of the brick-earth and the gradual passage into it of the gravel below, we are led to the conclusion that between the deposition of the gravel and that of the brick-earth, there was a general amelioration of climate. Can the "Trail" be referred to ice-agency? In my opinion it can, and for the following reasons: The contortion of the Drift when seen on a large scale, can only be ascribed to a heavy weight ploughing through and over it; also the position of the pebbles, which have, as a rule, their long axes in a vertical

* "Handbook of the London Geological Field Class."
† *Geol. Mag.*, vol. ix, pp. 268-9.
‡ "Geol. of London," vol. i, p. 636.

position, showing that the force was exerted in a vertical and not in a horizontal direction. The occurrence, noted when discussing the Ilford section, of an elephant tusk crushed by the "Trail," is very weighty, if not conclusive, evidence as to the cause of this phenomenon.

From this evidence there seems but one conclusion to be drawn. The earlier part of the period was undoubtedly characterised by a severe climate as shown by both the stratigraphical and the palæontological evidence. Contrasting, however, the abundance either in numbers or in species, or contrasting the conditions of life of representatives of the Low-Terrace mammalia now living, with those exhibited by the representatives of the High-Terrace deposits, we are forced to the inevitable conclusion that all these facts tell of a less rigorous climate, and of conditions that would be impossible, unless we regard these deposits as belonging to one of the interglacial periods since the formation of the great Chalky Boulder Clay. That the severe conditions returned once more is shown by the presence of the "Trail."

The succession of the Pleistocene deposits of the Lower Thames Valley may be tabulated as follows:

4. Trail	Close of Palæolithic period.	Cold period.
3. Middle Terrace Gravels (in part) and Brick-earths	Newer Palæolithic	Genial period.
2. Middle Terrace Gravels (in part) ... ... 1. High Terrace Drift ...	Older Palæolithic	Cold period.

My especial thanks are due to the following gentlemen: to Dr. Frank Corner, M.R.C.S., F.G.S., for the loan of specimens from his collection; to Mr. A. S. Kennard and Mr. B. B. Woodward, F.L.S., F.G.S., for their kind determination of the Ilford mollusca; to Mr. E. T. Newton, F.R.S., and Mr. H. A. Allen, for their aid in naming the mammalia, and also to Mr. Pringle, M.A., B.Sc., of the Museum of Practical Geology, for his kindness in connection with this paper.

THE PLEISTOCENE NON-MARINE MOLLUSCA OF ILFORD.

By A. S. Kennard and B. B. Woodward, F.G.S., F.R.M.S.

(Read June 2nd, 1899.)

IN 1890 an account of the non-marine mollusca from this locality was read before the Association by one of us, and was published in the PROCEEDINGS.* Since then Dr. Frank Corner, M.R.C.S., F.G.S., has collected extensively at Ilford, and the results of his labours were given by us in 1897.† During the last four years Mr. M. A. C. Hinton has also worked at these beds, and he very kindly placed his collection at our service. We now possess a fair knowledge of the mollusca from the Pleistocene brick-earths of Ilford. In the first place it must be remarked that the older collections were all made from the Uphall pit, whilst the specimens in the cabinets of Messrs. Corner and Hinton were obtained from the pit variously known as Sam's Green, Page's or the Cauliflower pit. Since the Uphall examples are from a slightly lower level, there is perhaps a difference in age, and it is advisable to list them separately on this account. With regard to the occurrence of the Uphall specimens Dr. Cotton remarked, "The two genera of shells of which hundreds may often be obtained at one visit are *Helix* and *Cyrena*, but *Unio* and *Planorbis* are not uncommon, and *Ancylus*, *Succinea*, *Valvata*, *Limnæus*, *Cyclas*, and *Paludina* have been discovered. They are chiefly seen in the layers of sand upon which the brick-earth reposes, and beneath the bones that are sometimes intermixed with them, and have been found even within their cavities. They appear to be partial in their distribution, and are not met with in the former cutting" [*i.e.*, on the North side of London Road, Curtis' brickfield].‡ The examples from Sam's Green pit are scarce and occur chiefly at one level, but single examples may be found scattered throughout the mass of brick-earth. In spite of the former abundance of shells in the Uphall pit hardly any trouble was taken to collect examples; but it is quite possible that many specimens may still exist in old collections. There are only two series known to the Authors, one in the Natural History Museum, and the other in the Museum of Practical Geology. Twenty-two species are represented, viz.:

* B. B. Woodward, "On the Pleistocene (Non-Marine) Mollusca of the London District," *Proc. Geol. Assoc.*, vol. xi, pp. 335-388.
† A. S. Kennard and B. B. Woodward, "The Post-Pliocene Non-Marine Mollusca of Essex," *Essex Naturalist*, vol. x, pp. 87-109.
‡ R. P. Cotton, "On the Pliocene Deposits of the Valley of the Thames at Ilford," *Ann. and Mag. Nat. Hist.* xx (1847), p. 165.

Vitrea nitida (Müll.).	*Planorbis albus*, Müll.
Eulota fruticum (Müll.).	„ *marginatus*, Drap.
Vallonia pulchella (Müll.).	„ *lineatus* (Walk.).
Hygromia hispida (Linn.).	*Bythinia tentaculata* (Linn.).
Helicella caperata (Mont.).	„ *leachii* (Shepp.).
Helix nemoralis, Linn.	*Valvata piscinalis* (Müll.).
Cochlicopa lubrica (Müll.).	*Unio pictorum* (Linn.).
Succinea putris (Linn.).	„ *tumidus*, Retz.
Limnæa peregra (Müll.).	*Corbicula fluminalis* (Müll.).
„ *palustris* (Müll.).	*Pisidium amnicum* (Müll.).
„ *truncatula* (Müll.).	„ *fontinale*, Drap.

The following nine species have been recorded, but no examples of them are known:

Vitrea fulva (Müll.).	*Succinea oblonga*, Drap.
Pyramidula ruderata (Stud.).	*Carychium minimum* (Müll.).
Pupa muscorum (Linn.).	*Ancylus fluviatilis*, Müll.
Vertigo antivertigo (Drap.).	*Limnæa auricularia* (Linn.).

Planorbis corneus (Linn.).

There is no inherent improbability in any of these records, but it would be more satisfactory if examples were known of *Pyramidula ruderata* (Stud.). The record is on the authority of Dr. J. Gwyn Jeffreys, who, in 1869, during the discussion following a paper by Professor W. Boyd Dawkins "On the Distribution of the British Postglacial Mammals,"* mentioned that this species and *Eulota fruticum* occurred at Ilford. Examples of the latter are, of course, known, but Mr. W. H. Dall informs us that there are no examples of *P. ruderata* in Dr. Jeffreys' collection, which is now at Washington. It is extinct in this country, and is only known fossil from three localities, Barnwell, Copford, and Clacton, although, of course, it is still an abundant form on the Continent, ranging as far north as Sweden.

Dr. Corner's collection from Sam's Green pit contained twenty-four species, whilst twenty-seven were represented in Mr. Hinton's, the combined list showing a total of thirty-four, viz.:

Vitrea nitida (Müll.).	*Vertigo antivertigo* (Drap.).
„ *nitidula* (Drap.).	*Succinea putris* (Linn.).
Vallonia pulchella (Müll.).	„ *elegans*, Risso.
Hygromia hispida (Linn.).	*Limnæa peregra* (Müll.).
Helicigona arbustorum (Linn.).	„ *palustris* (Müll.).
Helix nemoralis, Linn.	„ *truncatula* (Müll.).
Helicella virgata (Da Costa).	„ *stagnalis* (Linn.).
„ *caperata* (Mont.).	„ *glabra* (Müll.).
Pupa cylindracea (Da Costa).	*Planorbis glaber*, Jeff.
muscorum (Linn.).	„ *carinatus*, Müll.

* *Quart. Journ. Geol. Soc.*, vol. xxv, p. 192.

Planorbis marginatus, Drap.
„ *vortex* (Linn.).
„ *spirorbis* (Linn.).
„ *contortus* (Linn.).
„ *lineatus* (Walk.).
Bythinia tentaculata (Linn.).
Valvata piscinalis (Müll.).
Valvata cristata, Müll.
Corbicula fluminalis (Müll.).
Anodonta cygnæa (Linn.).
Sphærium corneum (Linn.).
Pisidium amnicum, Müll.
„ *astartoides*, Sandb.
„ *pusillum* (Gmel.).

Of these no less than sixteen species are unknown from Uphall, whilst there are seven species from that locality as yet unrecorded from Sam's Green pit. Two species, *Vertigo antivertigo* and *Pupa muscorum*, recorded from Uphall, but of which no specimens can be traced, are now listed from Sam's Green pit.

NOTES ON THE SPECIES FROM SAM'S GREEN PIT.

Helicella virgata is represented by a single example, and its occurrence is of great interest, since it is unknown in any other deposit, either Pleistocene or Holocene, of the Thames Valley. It was fairly common in the Pleistocene of Barnwell, and is not rare in a hill-wash, of Neolithic age, at St. Catherine's Down, Isle of Wight. Elsewhere it is unknown in any pre-Roman deposit, though, at the present day, it is one of the most abundant shells, and is gradually extending its range.

Pupa cylindracea has an even more curious geological history. It is known from the Norwich Crag at Bramerton, and has been recorded (but no specimens are known) from Clacton. It was common at Copford, but the age of that deposit is uncertain. It also occurs in similar beds at Chignal St. James', Felstead, Roxwell, and Shalford.

Of particular interest was a *Limnæa*, which differed so much from all recent British forms that we invoked the aid of Dr. O. Boettger, of Frankfort, who informed us that it was quite new to him, but was near *L. palustris*, var. *diluviana*, and this example, with other Ilford shells, was presented to the Natural History Museum by Dr. Corner. It is to be hoped that more examples of this form may yet be found.

Vitrea nitidula has hitherto been unrecorded from Ilford. This species is known from the Pleistocene of Barnwell, of north-east London, and from Copford. It has been recorded from Grays by Mr. S. V. Wood, but no examples can be traced.

All the examples of *Corbicula fluminalis* from Sam's Green pit are immature. An example of the dwarfed form of *Limnæa palustris*, which occurs in the Pleistocene of Harwich and Crayford, is in Mr. Hinton's collection.

Planorbis vortex is only represented by two examples; whilst *P. spirorbis* is the most abundant of the genus. *Valvata piscinalis*, so abundant at Grays, Crayford, and other Pleistocene localities,

is only represented by four examples of the normal form. The variety known as *V. antiqua*, Sby., has not been met with. The characteristic Pleistocene forms, *Planorbis glaber* and *Pisidium astartoides*, are also of great interest.

The occurrence of a single example of *Limnæa glabra* is of the greatest importance. This species is at the present day a widely-distributed form in these islands, but it has not hitherto been recorded fossil. It was unlikely that so widespread a form should be a recent introduction, and the Ilford example enables us to fill up a gap in the geological record.

It will thus be seen that recent work in this well-studied locality has greatly added to our knowledge, and we trust that the good work may be extended to other Pleistocene deposits, and so enable us to present an accurate list of their contained fossils.

[Since this paper was read Mr. J. P. Johnson has called our attention to a large series of mollusca in his collection, obtained at Uphall. There are thirty-one species represented, of which no less than fourteen are new records, viz.:

Agriolimax agrestis (Linn.)	*Clausilia bidentata* (Ström.)
Vitrea crystallina (Müll.)	„ *laminata* (Mont.)
Arion ater, Linn.	*Succinea elegans*, Risso
Punctum pygmæum (Drap.)	*Planorbis glaber*, Jeff.
Pyramidula rotundata (Müll.)	*Paludestrina marginata* (Mich.)
Helicella itala (Linn.)	„ *ventrosa* (Mont.)
Helix hortensis, Müll.	*Valvata cristata*, Müll.

There are five other species of which, though previously recorded from Uphall, no other examples are known to be extant, viz.:

Pupa muscorum (Linn.)	*Ancylus fluviatilis* (Müll.)
Carychium minimum (Müll.)	*Limnæa auricularia* (Linn.)

Sphærium corneum (Linn.)

Arion ater is indeed an interesting find, because it is a new record for the English Pleistocene, though it is known from deposits in France of the same age, and we have recently found it in several English Holocene beds. *Agriolimax agrestis* is now known from Ilford, Grays, and Crayford.

Punctum pygmæum is rare in any deposit, though it has been found at Copford, Barnwell, and West Wittering, in beds probably of Pleistocene age.

The occurrence of a single example of *Helix hortensis* furnishes additional proof of the presence of this form in this country in Pleistocene times. *Paludestrina marginata* is one of those species now extinct in this country which are of great interest. It occurs at Grays, but so far has been undetected at Crayford. The examples of *Sphærium corneum* are of the form so common at Crayford and known on the Continent as *Sphærium mænanum*, Kobelt.

The presence of several examples of *Paludestrina ventrosa* is noteworthy as tending to support the theory of more estuarine conditions than now exist. The numbers of species given above are of course materially altered by these new records.

We are greatly indebted to Mr. Johnson for his kindness in placing his collection at our service.]

ORDINARY MEETING.

FRIDAY, 3RD NOVEMBER, 1899.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

The following were elected Members of the Association: F. Coutts Antrobus, H. Arnold-Bemrose, M.A., F.G.S., W. B. Bannerman, F.L.S., F.G.S., James R. Brown, J. Herbert Hodd, F. Praed, H. Alfred Roechling.

The meeting then resolved into a Conversazione, and the following is a list of the exhibitors and their exhibits:

The DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY: Sheets 155, 248 (Drift and Solid), 282, 300, 315, 349, and 350 of the Geological Map of England and Wales, and Sheets 19, 85, and 115 of the Geological Map of Scotland.

J. J. H. TEALL, M.A., F.R.S.: Corundum from Scotland.

W. P. D. STEBBING, F.G.S.: The Association's Album of Geological Photographs; Crocidolite from S. Africa, Tertiary Ironstone from Frythe Park, near Epsom, and silicified Wood from Arizona.

A. E. SALTER, B.Sc., F.G.S.: Erratic igneous Rocks, consisting of Dolerites (Diabases), Rhyolites, etc., and microscopic slides of the same, from the Lea Valley, Cromer, Derbyshire, and various other localities.

Dr. G. ABBOTT: Various types of Concretions in Limestone, Iron, and Silica.

A. K. COOMARA-SWAMY, F.G.S.: Corundum and other minerals from Ceylon, Sections of Rocks from Ceylon and Brittany, and Cambrian Fossils from Skye.

W. H. CHADWICK and PERCY EMARY, F.G.S.: A series of Graptolites from the Wenlock Shale and Llandeilo Beds of Builth and Llandrindod, and from the Llandeilo Beds of Abereiddy Bay, near St. David's.

Prof. T. G. BONNEY, D.Sc., LL.D.: "Dreikanter" (windworn stones) from Egypt and New Zealand; and Schistose Jurassic rocks with minerals mistaken for garnets and staurolites, etc., from the Alps.

F. A. BATHER, M.A., F.G.S.: A quartzite Pebble from a Drift at Bowdon, Cheshire, with three facets on one surface (the property of R. D. Darbishire, Esq.); also similarly shaped pebbles from near Reval in Esthland, from Hokitika, New Zealand,

and from Prague, composed of various materials, but all known to have been sculptured quite recently by the erosive action of wind-blown sand.

Miss C. A. Raisin, D.Sc.: Specimens and microscopic sections of Granite and contact metamorphic Rocks from Barr-Andlau, Vosges; Enstatite Serpentine and garnetiferous Serpentine from the Vosges; and Lavas, Volcanic Bombs, and Sandstone fragments with vitrified surfaces from the Eifel.

Rev. Prof. J. F. Blake, M.A., F.G.S.: A series of English and Indian *Trigoniæ*.

Miss M. C. Foley, B.Sc.: Carboniferous Limestone Fossils, Dolerite and associated rocks, etc., collected during the Derbyshire Excursion (August, 1899).

W. F. Gwinnell, B.Sc., F.G.S.: Red Chalk of Hunstanton, with photographs and drawings; and Miocene Fossils from the Faluns of Touraine.

Henry Preston: Fossils from the Red Chalk of Hunstanton.

W. Whitaker, B.A., F.R.S., Pres. G.S.: An album of photographs of the members of the Société Belge de Géologie, Paléontologie et Hydrologie, being a pleasing memorial of their recent visit to this country and of the excursions in which they took part, some of which were arranged by the Association.

J. Parkinson, F.G.S.: A series of volcanic rocks from Vesuvius and the Naples district, and photographs of Vesuvius, including some taken during the eruption of 1872.

Francis R. B. Williams: A section across England and Wales, by William Smith. Published by John Carey in 1817.

W. H. North: Memoir descriptive of William Smith's Geological Map of England and Wales published in 1815.

John Sheer: Pebbles showing two infiltrations and faulted veins from near Boscastle, North Cornwall, Palæolithic Implements from Sussex, and a quartz geode from the beach at Worthing.

A. S. Foord: Photographs of frescoes in the Historical Museum at Moscow, representing life in Russia during the Stone Age, etc.

H. W. Monckton, F.L.S., F.G.S.: Photographs taken in Norway and Dorsetshire.

A. Smith Woodward, F.L.S., F.G.S.: Remains of skin and skull of *Neomylodon listai* from a cavern near Last Hope Inlet, Patagonia. (Exhibited on behalf of Dr. F. P. Moreno, Director of La Plata Museum.)

Miss Caroline Birley: A fine series of Carboniferous Limestone Cephalopoda from the Isle of Man, including some large specimens of *Actinoceras*, *Solenocheilus*, and *Prolecanites*.

H. W. Burrows, A.R.I.B.A.: Mollusca from the Faluns de Touraine (Helvetien Inférieur).

G. E. Dibley, F.G.S.: Hippurites from the Chalk of Cuxton and

Rochester (zones of *Rhynchonella cuvieri*, *Terebratulina gracilis*, and *Holaster planus*), *Goniaster* embedded in flint from the Middle Chalk of Cuxton, and other fossils from the Chalk and Lower Lias.

P. A. B. MARTIN: Chert implements from Broom, Dorset, and flint implements from France and Spain.

ORDINARY MEETING.

FRIDAY, DECEMBER 1ST, 1899.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

The President referred in sympathetic terms to the loss sustained by Geological Science and by the Association in the death of its former President, Dr. Henry Hicks, who for many years had taken an active part in furthering the objects and interests of the Association.

The following were elected members of the Association: Samuel Alsop, Mrs. H. Arnold-Bemrose, Henry Bassett, G. E. Blundell, Charles G. Cullis, C. J. J. Fox, H. G. Graves, Russell F. Gwinnell, W. J. Hall, C. R. Hewitt, H. Honwink, Miss J. A. Lee, Miss Susanna Lehmann, Miss F. M. G. Micklethwait, H. S. Romer, Major B. M. Skinner, H. W. G. Williams, Rev. E. H. Woolrych, F.R.G.S.

The following paper was read:

"The Zones of the White Chalk of the English Coast. I.—Kent and Sussex," by Dr. A. W. ROWE, F.G.S.

The paper was illustrated by diagrams specially prepared by Mr. C. Davies Sherborn, showing the distribution of the zones in the coast sections referred to in the paper.

A paper by Mr. W. H. Wickes on "A New Rhætic Section at Bristol" was postponed.

ORDINARY MEETING.

FRIDAY, JANUARY 5TH, 1900.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair

The following were elected members of the Association: John Chadwick, C.E., Walcot Gibson, F.G.S., Edmund W. Janson, Philip Lake, M.A., F.G.S., Frank M. Moir, James Parsons, B.Sc., John Scames.

Mr. R. Holland and Mr. J. E. Piper were elected Auditors.

The following paper was read:

"A New Rhætic Section at Bristol," by W. H. Wickes.

In the unavoidable absence of Sir Archibald Geikie through illness, Mr. F. W. Rudler delivered a lecture on "The last great eruption of Etna," illustrating his remarks by lantern slides and diagrams.

Mr. G. E. Dibley exhibited a flint with plates of *Pentacrinus* from the Chalk of Cuxton, and Chalk pebbles from the wash-mill at a cement factory at Strood.

THE ZONES OF THE WHITE CHALK OF THE ENGLISH COAST.

By Dr. ARTHUR W. ROWE, F.G.S.

I.—KENT AND SUSSEX.

WITH APPENDICES BY PROF. J. W. GREGORY, D.Sc., AND DR. F. L. KITCHIN, M.A., F.G.S.

THE CLIFF SECTIONS BY C. DAVIES SHERBORN

(Plates VIII, IX, X).

[*Read December 1st, 1899.*]

CONTENTS.

INTRODUCTION.

THIS paper is written by a field-worker for the use of field-workers, and in it no place can be found for long detailed stratigraphical sections, for descriptions of the microscopical characters of the rocks, and their chemical composition, or for general surveying. This can well be left in the more capable hands of the Geological Survey.

The writer pins his faith to Zoology, and to Zoology alone; for while it is true that broad lithological features give us a natural division-line between certain zones in some localities, it is equally clear that these same features fail us, in the case of identical zones, in other districts. But the fossils never fail us, if we collect with sufficient care, and as Murchison said in one of his unpublished letters, "palæontology carries the day."

No attempt will be made to crowd all the lithological details of a long coast-line, such as that at Dover or Beachy Head, into a small sectional diagram, as the overloading with details confuses the mind; and very often details, which are true at one part of the section, are misleading in another part. Where necessary, all salient lithological features will be noticed. A section along the coast has been prepared by Mr. Sherborn, wherein the dip of the beds has been indicated, and all prominent features on the cliff-top and shore-line have been noted, so as to serve, at the same time, the office of a 3-inch map. With this in hand, a field-worker can walk round the coast, and pick up the succession of beds with ease.

As this paper is the first of a series on the English Coast-sections, it would be well to define the life-zones in the first instance. Anyone reading the paper will know, at the outset, what the writer means, even though the conclusions herein set forth may not meet with his approval.

SUMMARY OF ZONES, WITH LITHOLOGICAL FEATURES AND ZOOLOGICAL CHARACTERISTICS.

The zones discussed in this paper are as follows, in descending order, the typical fossils being printed in column:

Zone of Actinocamax quadratus.

A firm marly chalk, with marl-bands and lines of nodular and tabular flints. The dominant fossil is *Cardiaster pillula*, though the Belemnites are generally considered to be the most characteristic.

a. Actinocamax (*Belemnitella*) *quadratus* in upper part } *C. pillula*
b. Actinocamax (*Belemnitella*) *merceyi* in lower part } throughout.

Other characteristic fossils are *Trochosmilia* (*Cœlosmilia*) *laxa*, *Bourgueticrinus* (a special form), *Echinocorys vulgaris* var. *gibbus*, and certain Bryozoa.

Zone of Marsupites testudinarius.

It will be impossible to draw up a scheme which shall embrace all the lithological features of this zone throughout the coast. The chalk varies from the pure flintless chalk of Margate to a marly, flinty rock, which one cannot distinguish from that of the zone above. The dominant fossils also vary so much in different districts that one can only give the broad divisions, which never vary.

a. Band of *Marsupites testudinarius*	zone of *Marsupites testudinarius*.
b. Band of *Uintacrinus*	

Characteristic fossils common to most sections are *Caryophyllia cylindracea*, *Bourgueticrinus* (a special form), *Echinocorys vulgaris* var. *pyramidatus*, *Terebratulina rowei*,* *Ammonites leptophyllus*, *Actinocamax merceyi*, and *Actinocamax verus*.

Zone of Micraster cor-anguinum.

Firm white chalk devoid, as a rule, of marly veins and bands, and invariably set with regular bands of nodular flint. Tabular flint lines rather common.

a. *Micraster cor-anguinum*	. . .	upper two-thirds.
b. *Micraster præcursor*	of group-form peculiar to this zone	lower third.
Micraster cor-testudinarium		

Other characteristic fossils are *Echinocorys vulgaris*, *Echinoconus conicus*, and *Epiaster gibbus*.

Zone of Micraster cor-testudinarium.

Uniformly in all sections a hard nodular chalk, with marly veins and pockets, and bands of hard, yellow chalk-nodules at intervals. Flints in irregular nodular bands, with occasional thin tabular bands. Marly bands rare.

Micraster præcursor	of group-form peculiar to this zone.
Micraster cor-testudinarium	

Other characteristic fossils are *Holaster placenta*, *Echinocorys vulgaris* var. *gibbus*, *Cidaris serrifera*, and certain Bryozoa.

* Described in Appendix B.

Zone of Holaster planus.

A hard, nodular chalk with marly veins and pockets, and hard, yellow, nodular chalk-bands; frequently with brown and green phosphatic nodules, and green grains of glauconite. Chalk-Rock may, or may not, be present. Flints in irregular nodular bands. Marly bands rare.

Holaster planus.
Micraster præcursor, } of group-form peculiar
Micraster cor-testudinarium, } to this zone
Micraster leskei.
Micraster cor-bovis.

Other characteristic fossils are *Pentacrinus* sp., *Cardiaster ananchytis*, *Cidaris serrifera*, *Cyphosoma radiatum*, *Echinocorys vulgaris* var. *gibbus*, *Holaster placenta*, *Terebratula carnea*, *Terebratulina gracilis*, *Rhynchonella cuvieri*, *R. plicatilis* var. *octoplicata*, *Turbo gemmatus*, and *Pleurotomaria perspectiva*. When present, which is by no means the rule, cephalopods and gasteropods are very characteristic.

Zone of Terebratulina gracilis.

A hard, white, marly chalk, with numerous marl-bands, and hard, nodular, chalk-bands. Nodular flint-bands may be rare, or very common. Tabular flint-lines rare.

Terebratulina gracilis.
Micraster cor-bovis.
Hemiaster minimus.
Inoceramus labiatus.

Other characteristic fossils are *Holaster planus*, *Holaster placenta*, *Discoidea dixoni*, *Echinoconus subrotundus*, and *Rhynchonella cuvieri*.

Zone of Rhynchonella cuvieri.

A hard, white, marly chalk, with hard nodular beds. Usually a flintless chalk. In the lower part of the zone the chalk is intensely hard, and gritty from broken fragments of fossils, forming, in most instances, the characteristic "grit-bed." Marl-bands rare.

Rhynchonella cuvieri } common throughout.
Inoceramus labiatus }

Other characteristic fossils are *Discoidea dixoni*, *Echinoconus subrotundus*, *Echinoconus castanea*, *Hemiaster minimus*, *Cardiaster pygmæus*, *Glyphocyphus radiatus*, *Ammonites cunningtoni*, and *Ammonites peramplus*.

DIVISIONS OF THE CHALK.

		Barrois, 1876.	Divisions adopted in this paper.	Phillips, 1819.	Geological Survey, 1861.	British Sub-Committee Geological Congress, 1888.	French Authors.	German Authors.
White Chalk.	Sénonian.					Danian.	Garumnien. Maestrichtien.	
		Z. à Belemnitelles ...	B. mucronata ... A. quadratus ...	Chalk with numerous flints.	Upper Chalk with flints.	Upper Chalk = Sénonian		Lemberg Chalk.
		Z. à Marsupites ...	Marsupites-band*... Uintacrinus-band...				Campanien.	Quadersandstein (Upper)
		Z. à cor-anguinum ...	M. cor-anguinum ...					
		Z. à cor-testudinarium...	M. cor-testudinarium	Chalk with few flints.			Santonien.	Quader mergel. Pläner mergel.
	Turonien.	Z. à H. planus	H. planus	Chalk without flints.	Lower Chalk without flints.	Middle Chalk = Turonian.	Angoumien.	Pläner (Upper).
		Z. à T. gracilis... ...	T. gracilis					
		Z. à I. labiatus... ...	R. cuvieri				Ligérien.	Pläner (Middle).
Grey Chalk.	Cénomanien.	Z. à B. plenus	A. plenus	Grey Chalk	Chalk Marl	Lower Chalk.	Carentonien.	Pläner (Lower).
		Z. à H. subglobosus ...	H. subglobosus ... Chalk Marl ...	Chalk Marl				
		Chloritic Marl	Chloritic Marl			Upper Greensand.	Rotomagien.	Quadersandstein (Lower).
		Z. à P. asper						
		Z. à Am. inflatus ...						

NOTE.—This tabular summary is given so that the divisions adopted in this paper may be compared with those arranged by previous writers on the English Chalk, and in order to afford a comparison with Continental equivalents. (Grey Chalk is not referred to in this paper.)

* *Marsupites testudinarius*-zone, divided by us into
Marsupites-band.
Uintacrinus-band.

PART I.

Coast of Kent.

A. Gore End (Birchington) to Kingsgate.

Zone of Marsupites testudinarius.

In the case of the Thanet Coast the danger of being caught by the tide is very small. Many parts may be worked even at high tide, and the "gaps" on the shore are so numerous that escape can easily be made. The only really dangerous place is west of Collins' Gap, between Margate and Westgate, and at the east end of Westgate itself. Here the tide rises very high, and comes up with great speed. Two other places to be mentioned are White Ness, at the east side of Kingsgate, and the section between Ramsgate and Pegwell, where there are no gaps, and where the shore is in places of a very soft and treacherous nature.

The only papers which will be quoted in reference to the Thanet Chalk will be Dr. Barrois'* famous "Recherches" and that published by Mr. Bedwell in the Proceedings, as none of the others deal with the subject from the zonal standpoint. Mr. Bedwell's† observations on Ammonite distribution are so accurate, and have been of so much value to zonal workers in Thanet, that it is a source of regret that his investigations were limited to these two papers. The line of scattered flints is the one prominent lithological feature in the Thanet *Marsupites*-chalk, and, to mark our indebtedness to the author, it will be alluded to in this paper as the "Bedwell-line."

Starting from the west end of Gore-end Bay, the cliffs are only about 25 ft. high, and 15 ft. from the base is seen a thin and ill-marked line of nodular flints. This is the "Bedwell-line." It is by no means easy to follow this line, as it is often interrupted, and in some places it is quite as easy to follow the line of the Ammonites themselves, as in this part of the coast they extend nearly up to the flint-line. In following the "Bedwell-line" a valuable aid will be found in a yellow sponge-bed, which occurs with considerable constancy two or three feet below it, and can be traced throughout the section.

The "Bedwell-line" rises as one goes east, until it is 20 or 25 ft. up the cliff at Westgate Bay, and still higher in the little headland

* "Recherches sur le terrain crétacé supérieur de l'Angleterre et de l'Irlande, 1876."

† F. A. Bedwell, "Ammonite Zones of the Isle of Thanet," *Proc. Geol. Assoc.*, vol. iii, No. 5, April, 1874; *Geol. Mag.*, dec. ii, vol. i, p. 16, 1874.

which divides the last-named from St. Mildred's Bay. It almost reaches the top of the cliff between St. Mildred's Bay and the Royal Sea-Bathing Hospital. At the latter point the cliffs become very low, and the flint-line drops rapidly. The cliffs appear again at Fort Point, Margate, and here the "Bedwell-line" is 40 ft. up the cliff. From this point it gradually sinks until it reaches 30 ft. at Hodges' Flagstaff, and falls to the shore-line at Foreness Point, to rise again beyond the sewer outfall, until it reaches White Ness Point (68 ft. high), where it passes out at the top of the cliff, and is seen no more until we pick it up again at Pegwell. The only point where it is lost is in the low cliffs of Botany Bay, where it temporarily passes out at the top of the cliff on the north side, to reappear, as the cliff rises, on the other side of the bay. At Pegwell we see it again for about one-third of a mile, when, after passing through a series of faults, it suddenly drops to the shore-line, and sinks into the sand.

"Barrois' sponge-bed," which forms the base of the *Marsupites*-zone, rises from the sand on the south side of White Ness Point, and is 21 ft. above "Whitaker's 3-inch" tabular flint-band, which rises from the shore under Kingsgate Castle. The association of these two lithological features will be traced when we deal with the zone of *Micraster cor-anguinum*. For the moment, suffice it to say that they can be followed, where the cliffs are high enough, as far as the north-east side of St. Margaret's Bay. The band of *Echinoconus conicus* lies immediately above "Barrois' sponge-bed" on the south side of White Ness Point.

The importance of the "Bedwell-line" as a lithological feature marking a zoological break will be seen in the zoological summary on page 296. Speaking broadly, *Actinocamax merceyi* and *Marsupites testudinarius* do not occur below it, and *Uintacrinus*, *Ammonites leptophyllus*, and *Actinocamax verus* do not pass above it. When Bedwell discovered the important relationship of the flint-line to the Ammonite-bed, he had no idea of its relationship to the equally important zonal fossils. It would be absurd to imagine that the "Bedwell-line" forms a hard-and-fast line of demarcation, for we know that life-forms begin gradually, and die out gradually.

The *Marsupites*-chalk is one of the typical beds of the "Chalk with numerous flints" of the older writers; but in not a few districts it is almost flintless.* The chalk is soft and holds much moisture, and can easily be worked with a pocket-knife. No marl is found either in veins or bands, and, in consequence, the fossils can be cleaned, wet or dry, with equal ease, and beautiful results may be obtained by working them out with the dental-engine.† The flints are solid and black, with a

* It is practically a flintless chalk in Thanet.
† A. W. Rowe, *Natural Science*, vol. ix, No. 57, November, 1896.

thin white cortex. A notable general feature of this chalk is the lines of vertical jointing, which run north-west and south-east. The coast is riddled with caves, all due to the jointing. From Birchington to Margate the chalk is very much broken up, but in the remainder of the section it is more compact. The beds rise as we trace them from Foreness to Ramsgate. This is the finest section of *Marsupites*-chalk in existence, and the sandy shore and the abundance of gaps make the working of it peculiarly easy. There are no less than seven miles of this comparatively rare bed, all in excellent condition for working.

THE BROAD ZOOLOGICAL DIVISIONS OF THE ZONE OF MARSUPITES TESTUDINARIUS.

a. *Marsupites testudinarius* *Actinocamax merceyi* *Echinocorys vulgaris* var. *pyramidatus* *Bourgueticrinus* (a special form) *Terebratulina rowei*	Band of *Marsupites testudinarius*, 48 ft. exposed.	Zone of *Marsupites testudinarius* 116 ft.
.... the "Bedwell-line."		
b. Band of *Echinocorys vulgaris*, var. *pyramidatus*. *Uintacrinus* *Actinocamax verus* *Ammonites leptophyllus* c. *Echinocorys vulgaris* var. *pyramidatus* *Bourgueticrinus* (a special form) *Terebratulina rowei* d. Band of *Echinoconus conicus*.	Band of *Uintacrinus*, total thickness, 86 ft.	
vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv "Barrois' sponge-bed" the base-line of the zone.		

Other characteristic fossils are *Porosphæra*, *Cyphosoma kōnigi*, *Micraster cor-anguinum* var. *rostratus*, *ZeugIopleurus rowei*,* *Serpula turbinella*, *Rhynchonella plicatilis*, *Terebratulina rowei*, *Kingena lima*, and *Lima hoperi*.

It will now be well to examine more closely the mutual relationship of the chief guide-fossils in this zone, and they will be discussed *seriatim*.

Marsupites testudinarius is essentially a gregarious fossil, for when it is found, it is found abundantly. It has been collected from the top of the cliff at Foreness Point, 48 ft. above the "Bedwell-line." The lowest record is that of a perfectly smooth test, found 30 ft. below that line, at Hodges' Flagstaff. It can be collected anywhere along the section in fallen blocks from the top of the cliff, but the best results will be obtained at Gore-End Bay, east of Collins' Gap, and especially at Foreness Point. At these localities the "Bedwell-line" sinks near the shore, and the fossil comes within reach. For this reason we can generally find plates for 200 yards west of the target. The great storm of November, 1898, brought down much chalk from the top of the cliff, and

* Described in Appendix A.

Marsupites plates could then be found in abundance all along the section on the fallen blocks.

In Thanet, all the evidence points to the existence of the smooth and small plates in the base of the *Marsupites*-band, and the early sporadic occurrences in the *Uintacrinus*-band point in the same direction. Where the plates are largest and most abundant, there the ornamentation is most marked. It would also seem that the plates become smaller and smoother again before they die out, though the data on this point are not so abundant and conclusive. Much the same appears to occur in the Sussex Chalk. We have never found *Marsupites* in the zone of *Actinocamax quadratus*.

Actinocamax merceyi.—Field-workers owe a debt of gratitude to Dr. Barrois for familiarising this important zonal form (which was founded by Mayer-Eymar), and for the separation of it from *Actinocamax quadratus*. In the sections worked by the writer, it generally passes down into the *Marsupites*-band, and occupies the lower part of the *Actinocamax quadratus*-zone. In this section its range is coincident with that of *Marsupites* itself, and it can generally be found at Foreness Point, where the plates are thickest. Many rolled examples may be picked up on the reefs. The lowest record was at Newgate Gap, 30 ft. below the "Bedwell-line." It is not a common fossil in any section which we have worked. This is not the place to discuss the anatomical details of the fossil, but it may be mentioned that the alveolar cavity is much shallower than that of *Actinocamax quadratus*. A paper on the Belemnites of the Chalk will shortly be published by Mr. G. C. Crick, in which will be incorporated all the stratigraphical details obtained on the coasts of Kent, Sussex, and Dorset.

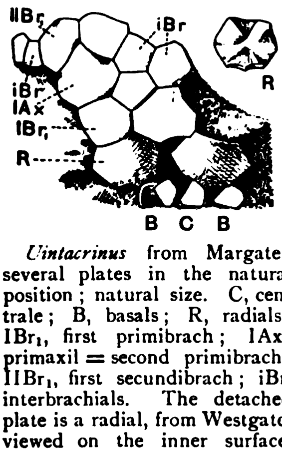
Echinocorys vulgaris var. *pyramidatus* is very abundant, and a thick band with this fossil may be found immediately below the "Bedwell-line." This band is an unvarying feature from Birchington to Kingsgate. So common and characteristic is this urchin throughout the whole thickness of the *Marsupites*-zone, wherever it occurs, that the writer would feel justified in assigning, by its presence in quantity, any quarry to this zone, even if plates of *Marsupites* or *Uintacrinus* were not discoverable. A large dome-shaped variety of *Echinocorys vulgaris* is met with in the *Uintacrinus*-band, and less commonly in the *Marsupites*-band. A paper on *Echinocorys* is in course of preparation. The *Echinocorys*-band is a local feature only.

Bourgueticrinus forms a very useful guide to the whole of the zone, for wherever the writer has worked, there a certain form of head is found. It is nipple-shaped, and not of large size. (See Pl. VIII, Fig. 6.) A large barrel-shaped joint is also characteristic, but not so infallible a guide as the other, as it is also fairly common in the *M. cor-anguinum*-zone

The writer has not found the nipple-shaped form outside the *Marsupites*-zone.

A new *Terebratulina* has been described by Dr. F. L. Kitchin for this paper. It is found throughout the whole extent of the zone, wherever the writer has studied it, and though not absolutely limited to it, its occurrence in the zone of *Actinocamax quadratus* is so rare that it may be regarded as a reliable guide-fossil to the *Marsupites*-zone. The form found in the zone of *A. quadratus* differs so decidedly from that in the zone below that it would never mislead in the field. (See Appendix B, Pl. VIII, Figs. 1-5.)

Uintacrinus.—The whole of the base of this section is in the *Uintacrinus*-band, save the short portion at Foreness Point, where the *Marsupites*-band comes down to the shore-line. Its range is from the "Bedwell-line" to about 20 ft. above "Barrois' sponge-bed." Occasional plates may be found below the point mentioned, but it has never been found right down to the base-line of the *Marsupites*-zone in Thanet. It is a common fossil—as common as *Marsupites* is in its own band. As would be imagined, it mingles with the *Marsupites*, and plates belonging to both genera have been found on the same block of chalk by Mr. Sherborn, Mr. Upfield Green, Dr. F. L. Kitchin, and the writer. This fact is especially mentioned, as doubt has been expressed on this very point. The broad fact remains that where *Marsupites* is common, *Uintacrinus* is rare, and *vice versâ*.



Uintacrinus from Margate; several plates in the natural position; natural size. C, centrale; B, basals; R, radials; IBr_1, first primibrach; IAx, primaxil = second primibrach; $IIBr_1$, first secundibrach; iBr, interbrachials. The detached plate is a radial, from Westgate, viewed on the inner surface. Coll. A. W. Rowe. Gilbert C. Chubb del.; F. A. Bather dir.

It would be difficult to exaggerate the importance of *Uintacrinus* as a guide-fossil, for wherever we have worked this zone, there *Uintacrinus* has been found in its proper position in the lower part. It may be mentioned that we are never content to determine this zone by means of the arm-ossicles, but always rely on the plates of the test. The arm-ossicles are characteristic enough, but may be confused with those of *Marsupites*, *Ophiura*, or broken columnals of *Bourgueticrinus*. Nothing is like the irregular, polygonal *Uintacrinus* plate, with its strong ridges on the inner concave surface. This crinoid has proved to be one of the most important guide-fossils discovered during the last twenty years. The writer collected it twenty-five years ago, and was quite unaware of its generic name until Mr. F.

A. Bather* named the specimens sent up to him. It was then merely a matter of time to define its range, and gauge its zonal value. (See Fig. on p. 298.)

Actinocamax verus is a common fossil throughout the *Uintacrinus*-band, and it extends a good many feet above the "Bedwell-line," where *Marsupites* are abundant, but it then becomes rare. Its downward range is to the "Barrois sponge-bed," in which it has actually been found, but the writer has never found it below that level in Thanet, nor in the zone of *Micraster cor-anguinum* in any other locality. When it occurs, it is found abundantly, as a rule, but it is one of the unreliable factors of the zone, as it does not occur in every section. (See p. 348.)

Ammonites leptophyllus.—The range of this fine Ammonite is identical with that of *Uintacrinus*, and the fact that 105 were found, *in situ*, between Birchington and Kingsgate, proves that it is not rare. (The reader is referred to Mr. Bedwell's paper† for further information.) It rarely measures more than 3 ft. in diameter in this part of the Chalk. Its upward range is to the "Bedwell-line," only four examples having been found above that level, and then but a few feet above it. It has not been found within 15 ft. of the "Barrois sponge-bed." *Aptychus* has not yet been found in Thanet, nor did we meet with it in the zones of *Marsupites* or *Actinocamax quadratus* in Sussex.

Echinoconus conicus, though by no means confined to this zone or diagnostic of it, must be mentioned, as it occurs as a thick band above the "Barrois sponge-bed," through which it passes into the zone below. The upward range is to the *Marsupites*-band, but it is a rare fossil above the "Bedwell-line." Dr. Blackmore says that, at Salisbury, it is common at the base of the *Marsupites*-zone, though it does not form a band as it does in Thanet. At the south side of White Ness Point the *Echinoconi* are so thickly packed that they are crushed one into another. *Echinoconus globulus* is found in Thanet at the base of the *Marsupites*-zone, and at the extreme top of the *M. cor-anguinum*-zone. We have not found it in Sussex or Dorset. It is a rare fossil.

Porosphæra is a useful guide-fossil. All three forms are common, and *Porosphæra globularis* reaches its maximum size in this zone. The large size of this form is a useful fact to know in the field.

Caryophyllia cylindracea is not a common fossil, but it is characteristic of the zone in Thanet, and at Salisbury also, according to Dr. Blackmore. At present we have not found it in Sussex. *Parasmilia centralis* is the usual form, and is fairly abundant, but it is not reliable as a guide-fossil. The corals in this zone are rarely of large size. *Parasmilia granulata* is

* *Geol. Mag.*, N.S., decade iv, vol. iii, pp. 443-445, October, 1896.
† *Op. cit.*

found, but is not so common as in the zone of *Micraster cor-anguinum.*

A new *Zeuglopleurus* has been described for this paper by Dr. Gregory. It occurs both above and below the "Bedwell-line" in Thanet, but has not been found at present in other sections of the *Marsupites*-zone. (See Appendix A, Figs. 1-4, p. 354.)

Salenia geometrica is never really common, though we have found a fair number of specimens in the *Marsupites*-zone, at Margate, especially in the *Uintacrinus*-band. It is still rarer in the zone of *M. cor-anguinum*, and rather more common again in the *Actinocamax quadratus*-zone.

Micraster cor-anguinum var. *rostratus*—the *M. rostratus* of Mantell and Bucaille—occurs in this zone. It is not a species, but merely a zonal variation, with an exaggeration of the strong carination characteristic of the high-zonal series of *Micraster.* It is, however, of use to us as a guide, and as such it is here recorded.

Serpula turbinella, though by no means confined to this zone, is a characteristic fossil, and is commoner here than in the zones immediately above or below it.

Rhynchonella plicatilis is only found at the lower part of the *Uintacrinus*-band in Thanet, and is there a rare fossil. This is in marked contrast to its abundance throughout the whole zone in Sussex, especially in the *Marsupites*-band.

Kingena lima, of a small, round variety, is fairly common throughout the zone, and is useful, as it is very rare in the zone of *Actinocamax quadratus*, and is far from common in that of *Micraster cor-anguinum.* This form differs considerably from the large examples found in the zone of *Belemnitella mucronata.*

Ostrea alæformis, Woodw. (Woodward's "Geol. Norfolk," pl. vi, figs. 1, 2, 3), is not uncommon in this zone in Thanet. We have seen no figure which exactly reproduces these forms from the *Marsupites*-zone, but they more resemble Woodward's figures, and Norwich (*B. mucronata*-zone) specimens, than any others. We have seen a variation of this form in the zone of *A. quadratus*, and it is probable that a series of zonal variations could be traced from one zone to another.

Lima hoperi is found throughout the zone in abundance, and is of very large size. In the writer's experience no other zone yields them in such numbers, or of such size.

A reference to the section of the Coast which accompanies this paper will show that letters have been used to indicate the position of the chief guide-fossils in this zone.

It has been objected that the name-fossil of this zone is not well chosen, and that this zone should be merged with the *Actinocamax quadratus*- and *Belemnitella mucronata*-zones above it. If ever a zone possessed a distinctive fauna it is the zone of *Marsupites testudinarius.* The main difficulty is that field-workers

do not recognise that the *Marsupites*-band is only a part of the *Marsupites*-zone, just as the equally important *Uintacrinus*-band is but a portion of it. It has been said that it should be merged into the *A. quadratus*-zone, because *Actinocamax merceyi* passes down from the higher zone into the *Marsupites*-band. The obvious reply to this is that the other guide-fossils of the *A. quadratus*-zone, such as the all important *Cardiaster pillula*, and the equally characteristic *Echinocorys vulgaris* var. *gibbus*, are limited to their own zone, and do not follow the downward range of *Actinocamax merceyi*. Moreover, there are sections of the *A. quadratus*-zone where *Actinocamax merceyi* is not found at all.

B. KINGSGATE TO ST. MARGARET'S BAY.

Zone of Micraster cor-anguinum.

This is a typical section of the "Chalk with numerous Flints" of the pre-zonal writers, and is of great length; for omitting the gap between Little Cliffs End and Kingsdown, we have just ten miles of this zone, every yard of which is easily accessible, and capable of yielding good results. The chalk is soft and white, more compact than the *Marsupites*-chalk, and devoid of marl. Nodular flint-bands occur with striking regularity, and tabular flint-bands are not uncommon. The most interesting of these is "Whitaker's 3-inch" tabular flint-band, which rises south-east from the sand, under Kingsgate Castle, 21 ft. below "Barrois' sponge-bed," and continues to rise until it reaches the North Foreland Lighthouse, from which point to the Coastguard Station at Broadstairs it keeps nearly horizontal. We pick it up again on the other side of Broadstairs, and carry it on to the south side of Dumpton Point, where the cliffs are lower, and the tabular band passes out at the top. Up to this point the tabular* has been imperceptibly rising until it reaches three-fourths of the way up the cliff. This takes us to Dumpton Gap, where there is a fault, bringing the tabular half-way down the cliff. Between here and East Cliff Lodge the chalk is faulted in several places, and the tabular is, in consequence, not quite horizontal. The tabular again rises gradually until, at Augusta Stairs, it is 25 ft. from the top.

There may be, here and there, a very thin cap of the *Marsupites*-zone along the North Foreland, but there cannot be much, as the "Barrois sponge-bed" can only rarely be seen, and that is 21 ft. above the "3-inch" tabular band; but from 300 yards south of Dumpton Gap to Augusta Stairs we have room for the *Uintacrinus*-band at the top of the cliff, and we find evidence of it in the presence of "Barrois' sponge-bed," and frequent fragments of *Ammonites leptophyllus* on the shore.

* A continuous bed of flint, as distinguished from the nodular bands of flints.—ED.

The tabular band can be traced in the cliff behind the L.C.D.R. Station, 75 ft. up from the base, and is easily picked up again in the West Cliff, where it is on a level with the cement string-course in Paragon Baths. It disappears just where the iron railings end, by the Liberty Boundary, and at the point where there are four arched brick supports to the cliff. We now see no more of it until we come to Pegwell, where we find it in the cliff at a point corresponding with the letter "H" in "Hotel," on the 6-inch map. It here dips rapidly to the south-west, and a little west of the Coastguard flagstaff there is a fault where the band disappears.

From the fault to the junction with the Thanet Sands we have to deal with the zone of *Marsupites*, as the dip to the south-west brings the upper beds to the shore. Under the flag-staff the cliff is 30 ft. high, and "Barrois' sponge-bed" is 12 ft. up. From this point the sponge-bed sinks to the west, and we soon walk upon the *Echinoconus*-band, and finally on *Uintacrinus*-chalk, with its abundant fossils. On the broken, grass-grown slopes west of the brick tunnel we found a few *Marsupites* plates associated with those of *Uintacrinus*; so this brings us to the level of the "Bedwell-line," which, however, is not recognisable. This short section of *Marsupites*-chalk is a complete epitome of that found west of Kingsgate, and the stratigraphical details and the fossils are identical.

There are no more chalk cliffs until we pass Kingsdown. Half-a-mile north-east of Hope Point the cliffs are about 60 ft. high, and half-way up we notice the line of flint, 30 ft. under "Whitaker's 3-inch band," mentioned by Bedwell in the *Geological Magazine.* * This is the line from which columns of nodular flints spring upwards; but the cliffs are not quite high enough to admit of the "3-inch" tabular being seen. However, at the rifle-range the "3-inch" tabular comes in again, and steadily rises until we reach the flagstaff, where it again passes out at the top of the cliff, to come in once more at Leather Court Point. Thence it steadily rises till we reach St. Margaret's Bay, where it is at the top of the cliff. Bedwell's "columnar band," underneath it, can be traced the whole way with ease, so that we are indebted to him for another excellent observation, without which it would have been impossible to have distinguished the "3-inch" tabular from any other thick tabular.

Up to Leather Court Point the cliffs are based by a turf-clad talus, and excellent collecting may be done along the top of the slope. From Leather Court Point to St. Margaret's Bay there is a shingle beach, and the cliffs are wave-worn. Beyond a few examples of *Micraster præcursor*, *Echinocorys*, and *Inoceramus*, the cliffs are very barren in this, the lowest part of the zone.

* *Op. cit.*

The Broad Zoological Divisions of the Zone of Micraster cor-anguinum.

Micraster cor-anguinum . .		upper three-fourths	280 ft.
Echinocorys vulgaris, of form peculiar to the zone . . .			
Echinoconus conicus . . .			
Epiaster gibbus			
Micraster præcursor	of group-form peculiar to this zone	lower fourth . .	
M. cor-testudinarium			
Inoceramus involutus . . .			

Other characteristic fossils are *Parasmilia*, *Onchotrochus serpentinus*, *Bourgueticrinus ellipticus*, *Cidaris sceptrifera*, *C. clavigera*, *C. perornata*, *Cyphosoma königi*, and *Terebratula semiglobosa*.

Fossils are uniformly distributed through the upper three-fourths of this zone, being perhaps a trifle more abundant at the top than elsewhere; but the base is nearly always singularly barren in organic remains, and this fact is so characteristic that a section with regular bands of nodular flints and a paucity of fossils can generally be recognised as the basal portion of this zone.

Micraster cor-anguinum is chiefly characteristic by reason of its abundance, though there are not a few sections in this zone where it is a somewhat uncommon fossil. The var. *latior* is always found in this zone.

Echinocorys vulgaris is abundant, and of many profile variations, two stand out as characteristic of the zone—a tall, dome-shaped form and an ovate form. The common ovate form is figured by Wright (Brit. Foss. Echin. *Palæontographical Society*, 1864—1882) on pl. 77, fig. 8, and the tall, dome-shaped form is shown in fig. 7 on the same plate. The var. *pyramidatus* is never seen in this zone in its full development, even at the top, and we have to wait until we pass into the zone above to find it. It is true, however, that the ovate form takes on a pyramidical tendency as we near the upper border of the zone, just as we have, at the extreme base of the zone, a trace of the gibbous shape which is so characteristic of the zone below.

Echinoconus conicus is always abundant, but its varieties in no way differ from those in the zone above. Its rarity increases the deeper we go in the zone.

Epiaster gibbus is at its maximum development in this zone, though it is never an abundant fossil. Very interesting passage-forms between it and *Micraster præcursor* are seen at the base of the zone.

Micraster præcursor and *M. cor-testudinarium* are only found in the base of the zone, and for details concerning *Micraster*

the reader is referred to the paper on that genus by the writer.*

Inoceramus involutus is not common, and is generally confined to the base of the zone. It is rarely preserved in a perfect state, and the writer has yet to obtain a complete example.

Porosphæra ceases to be of use as a zonal guide at this horizon. All three forms are fairly abundant, especially *Porosphæra globularis*. In this zone it is of medium size, and is abundant in every zone down to that of *Rhynchonella cuvieri*, but it is always of small size. *Porosphæra woodwardi* and *P. pileolus* are found as low down as the zone of *Holaster planus*, but they are comparatively rare fossils, especially the *Porosphæra woodwardi*.

Corals are abundant in this zone, and in our experience, *Parasmilia granulata* reaches its maximum development. *Parasmilia cylindrica* and *P. mantelli* are found, and are of a larger size than in any other zone. *Parasmilia centralis* var. *gravesana* is abundant. The nomenclature of this group is in an unsettled state, and it is probable that a widely extended zonal inquiry would materially reduce the number of species, and that the working of zonal variation would be more clearly emphasized. But the coral which is most characteristic in the upper part of the zone in Thanet is *Onchotrochus serpentinus*. In the writer's experience this is shown to be a local peculiarity.

Bourgueticrinus is abundant, and a stumpy head is rather characteristic, as well as a large and long columnar (Pl. VIII, Figs. 8 and 9). The characteristic columnar, however, is a medium-sized, barrel-shaped form, which is figured.

Cidaris spines are abundant, and *Cidaris sceptrifera*, *C. clavigera*, and *C. hirudo* are all common to this zone and the zone above, though they are found here in great abundance. *Cidaris perornata*, however, is certainly more special to this zone.

Cyphosoma königi reaches its maximum development in this zone, being rare in the zone of *M. cor-testudinarium*, fairly common in the *Marsupites*-zone, and comparatively rare in the zone of *A. quadratus*. *Cyphosoma corollare* and *C. spatuliferum* have the same range as *Cyphosoma königi*, and their relative abundance in the various zones is much the same.

Terebratula semiglobosa is common in this zone, in singular contrast to its rarity in the zone above.

Thecidea wetherelli begins to appear at the base of this zone, but it is rare. Directly we pass into the upper three-fourths of the zone it becomes abundant, and it ranges up to the *B. mucronata*-zone, being always a common fossil. We have recently examined hundreds of Micrasters, from the zones of *M. cor-testudinarium* and *H. planus*, and failed to find a single example upon them. Its downward range, therefore, in Kent and Sussex, would seem to be sharply defined.

*Quart Journ. Geol. Soc., vol. lv, August, 1899, p. 494.

This is one of the least satisfactorily named of the zones, as in spite of its great thickness, there is so little upon which one can depend in the matter of fossils which are common, and at the same time reasonably restricted to the zone in question. Also, from top to bottom of it, there is no salient lithological feature, with the exception of the "Whitaker 3-inch band"; and as that has no bearing on the faunal history of the zone, its value is confined to its relation to "Barrois' sponge-bed," and its position as a guide to the top of the zone in Thanet and at St. Margaret's Bay. There is no fossil which is entirely satisfactory as a zonal guide, and therefore the old name has been retained in this paper. *Epiaster gibbus* has been suggested, and it is a good guide-fossil, but far too rare to be of practical service; besides, it is relatively almost as common in the *Marsupites*-zone. *Echinoconus* is found abundantly, but so it is in the zone above. *Echinocorys vulgaris* is incomparably the most reliable form, and the writer is in the habit of using the shape-variations already mentioned as the most ready means of determining this zone in the field.

Inoceramus involutus has been lauded as a name-fossil, but chiefly on account of its greater prevalence in this part of the Chalk in France. A fossil so fragile and imperfect, as this always is with us, should only be adopted as a last resort; and the writer would ask the supporters of the proposed use of this shell as a zonal name-fossil, how many examples in a decent state of preservation they have in their cabinets? This is one of the most colourless zones with which we are acquainted, and the present name has been retained, not because it is a good one, but because there is nothing better wherewith to replace it.

The flints in this zone are black and compact, with a varying thickness of white cortex. They are not commonly "zoned," as at Beachy Head, as mentioned by Barrois.

The Survey measurement of 280 ft. has not been checked by the author, as the upper and lower limits of the zone are so strongly defined in Thanet that there is little possibility of error.

C. St. Margaret's Bay to Shakespeare's Cliff.

The Dover section has been admirably dealt with by Mr. Price* in the west cliffs, and by Mr. W. Hill† in the west and east cliffs, and there is another paper by Hébert,‡ which is interesting as a pioneer paper on the zonal question.

This section is so important that it will amply repay the observer to walk round the shore from St. Margaret's to Langdon Stairs, before doing any collecting. By this means a general

* *Quart. Journ. Geol. Soc.*, vol. xxxiii, 1877, pp. 431-448.
† *Ibid.*, vol. xlii, 1886, pp. 232-247.
‡ *Bull. Soc. Géol. de France*, sér. 3, t. xi. June 15, 1874.

idea of the position of the zones may be obtained, and calculations can be checked by examining the beds in succession during the ascent of the zig-zag at Langdon Hole (see p. 320).

It may be convenient to know that there is no way up from the shore between St. Margaret's and Langdon Stairs, and that there are two points at which the water rises very high, and to which it runs up quickly. These are at the south corner of St. Margaret's Bay, and at a point a little west of Cornhill Coastguard Station. However, the numerous falls afford a safe refuge, and we commonly arrange to be caught by the tide; but one wants to know the coast before doing this. Strong fresh-water springs are found all along this coast, notably at St. Margaret's, opposite Canterbury Hole, at a point north-east of Frenchman's Fall, at the junction of the *Holaster planus*- and *Terebratulina gracilis*-zones, and under the convict prison. These springs are on the reefs, and it is worth noting that wherever they occur the reefs are clad in a bright green sea-weed.

This is, on the whole, the grandest section from the zone of *Micraster cor-testudinarium* to that of *Rhynchonella cuvieri* in the south of England, every zone being well exposed, and in good order for working. From the south corner of St. Margaret's to 200 yards north-east of the Low Light is two-thirds of a mile, and all this is in the zone of *M. cor-testudinarium*. From this spot to the perpetual spring rising from the foot of the cliff, which coincides with a point north-east of the windlass at Bantam Hole, the section is cut in the zone of *H. planus*, and from the spring to Dover the cliff is in the Chalk with *Terebratulina gracilis*. The Chalk-Rock rises a little north-east of the submarine telegraph, near the South Foreland Light. On the west side of Dover are some good sections in the zones of *T. gracilis* and *R. cuvieri*, which can be worked in falls, and examined throughout their extent in the two zig-zags.

Zone of Micraster cor-testudinarium.

This is the "Chalk of many organic remains" of Phillips (*Trans. Geol. Soc.*, ser. 1, vol. 5, p. 24) and Whitaker's "nodular chalk of Dover" (*Mem. Geol. Survey*, 1872, "London Basin," p. 32). Both terms are apt, as the rugged, knotty nature of the beds is very apparent, and the abundance of fossils most striking. The flints are not in regular nodular bands as in the zone above, but irregular bands are not uncommon, and scattered flints are frequent. The flints are often spongiform. There are no marl-bands, but the chalk is greyish in colour from the presence of marly patches and veins This chalk is very curious, as we have hard yellow nodular bands, from which fossils can hardly be extracted, and soft patches from which they can be removed with a pocket-knife. The soft marly pockets are very rich in Bryozoa and

Foraminifera. The whole of the two-thirds of a mile of *M. cor-testudinarium*-chalk is in fine condition for working. The cliffs are tide-washed, but not battered by the shingle, and consequently afford the finest section of this zone in England.

The steady rise of the beds, as we pass round the coast, is here continued, and at the north-east corner of St. Margaret's Bay, under a small turf-clad talus, is the actual junction of the zones of *M. cor-anguinum* and *M. cor-testudinarium.*

On the white chalk flats in the bay one can collect *Micraster præcursor*, *M. cor-testudinarium* and *Echinocorys vulgaris* var. *gibbus*, the two first, of the group-form special to this zone, but bearing clear evidence of their passage to the forms special to the base of the zone above.

At the south corner of St. Margaret's Bay the cliffs are comparatively low, and are only 150 ft. high at Canterbury Hole, which is now obscured by a fall of cliff. We here have nothing but the chalk of the zones of *M. cor-testudinarium* and *M. cor-anguinum* to deal with, and the contrast between the two beds is very striking—one grey-yellow and nodular, with irregular lines of flints, the other smooth and white, with regular lines of flints. An idea may be obtained of the rate at which the beds are rising by noting that the junction of the zones of *M. cor-anguinum* and *M. cor-testudinarium*, which is on the shore-line at the north-east corner of the bay, is 37 ft. above the shore at Canterbury Hole.

At this point, we can count from the shore seven well-marked yellow nodular-chalk bands, from 5 to 7 ft. apart. The topmost yellow nodular band marks the junction of the zones of *M. cor-anguinum* and *M. cor-testudinarium.* Above this arbitrary line the paucity of fossils is as notable as the profusion below.

At the same place is seen a thin tabular flint-line, within the *M. cor-testudinarium*-zone, 11 ft. from the shore-line, and a second, and much thicker one, about 15 ft. above the last yellow nodular band. These are respectively the *M. cor-testudinarium*-tabular, and the basal *M. cor-anguinum*-tabular. Of course, the latter is quite different to the tabular mentioned before in the same zone. These two tabulars have been fixed upon, as we can follow them with ease as far as the zig-zag stairs in Langdon Bay, and with glasses they could, doubtless, be followed well into Dover. They are most useful as giving a fixed line, whereby we can follow the beds as they rise and pass out of easy vision. These two tabular bands are 44 ft. apart. Taking the *M. cor-testudinarium*-tabular as a datum-line, we find that at Frenchman's Fall it is 20 ft. from the shore-line, and 200 yards north-east of the Low Light it is 30 ft. from the shore-line.

Two hundred yards north-east of the Low Light we see three lines of nodular flint, the highest and lowest strong and continuous, and the middle broken up into two or three uncertain lines. The measurement between the highest and lowest lines is 15 ft., and the

distance between the *M. cor-testudinarium*-tabular and the upper of the two strong flint-lines is also 15 ft. We can thus get a thickness of this zone from the Canterbury Hole to 200 yards north-east of the Low Light.

From the *M. cor-testudinarium*-tabular, to the last nodular band .	26 ft.
" " " to the lower of the two strong flint-lines	30 ft.
Total	56 ft.

The lower of these two strong flint-lines is the approximate junction of the zones of *M. cor-testudinarium* and *H. planus*. The actual break is a purely zoological one, and takes place in the 15 ft. between the upper and lower of the strong nodular flint-lines, and this arbitrary limit is fixed entirely by careful collecting, for there is no definite lithological division. It is only another instance of the hopeless task of trying to establish hard-and-fast lithological boundaries for life-zones, which can only be settled by evidence offered by the fauna itself.

Typical Fossils of the Zone of Micraster cor-testudinarium.

Micraster præcursor / *M. cor-testudinarium*	of group-form peculiar to this zone.	56 ft.
Echinocorys vulgaris var. *gibbus*		

Other characteristic fossils are *Cidaris serrifera*, *Holaster placenta*, *Serpula ilium*, *Eschara acis*, *Heteropora pulchella*, *Reticulipora obliqua*, *Rhynchonella limbata*, *Terebratula semi-globosa*, and *Plicatula barroisi*.

There are no zoological divisions in this zone, as the dominant forms continue from top to bottom, and afford a notable and continuous facies. *Micraster* is the true guide, and for details the reader is referred to the paper on this genus, already quoted. We find no *Micraster* with "smooth" or "sutured" ambulacra in this zone, but they are all of the "strongly-inflated," or more commonly, of the "sub-divided" type. This applies equally to broad and narrow forms. The narrow forms greatly outnumber the broad, and in this section the latter are never really common.

Echinocorys vulgaris var. *gibbus* is very abundant, and is confined to this zone and the zone below. There is singularly little shape-variation of *Echinocorys* in this zone, and there are no sub-varieties to record. The *Echinocoridæ* are of a curiously uniform size, and are never very large, as in the two zones immediately above. It is worthy of note that a definite percentage of them have thin tests. So that there should be no mistake on this point some of them have been worked out, and they are true *Echinocoridæ*, and not Holasters.

The occurrence of a thin-tested *Echinocorys* appears to be fairly common at the base of this zone, and in the *H. planus*-zone, in all localities which we have worked; but we find a small percentage of tests with this peculiarity in all the zones which yield this urchin. The variation in thickness of the test, therefore, would seem to be much commoner than in *Micraster*, which is singularly constant in this particular. Save in the case of *Micraster cor-bovis* and of its passage-forms, where the test is invariably thin, it is very rare to find a *Micraster* with a thin test. *Micraster* is so plastic and variable in its essential features that one would have expected the reverse to be the case.

*Holaster placenta** is of frequent occurrence, and as many as three are often found in a yard of chalk. They reach a great size, being often over 80 mm. in length, and owing to the thinness of the test, are rarely obtained in a perfect state. The description and figure of this urchin are well worth studying, as comparatively few field-workers are conversant with this useful fossil. It is worth mentioning that *Holaster placenta* and *H. planus* can always be separated in the field, if the trouble is taken to remove and clean them, and that not a few records of *Holaster planus* in this zone are due to a lack of appreciation of the distinctions between the two species. *Holaster planus* does occasionally pass up into this zone, but it is rare. With *Micraster* for a guide there need be no difficulty in separating the zones of *M. cor-testudinarium* and *H. planus*.

The spines of *Cidaris serrifera* are found in profusion, and replace those of *Cidaris sceptrifera* and *C. clavigera*, which are so common in the twò zones above. This remark applies to the Dover section only.

Serpula ilium, though it occurs in the zones above, is never common until we reach this zone. At this level and below, it is always of small size, and is probably the commonest fossil.

Eschara acis is abundant both in this zone and the zone below. *Eschara lamarcki* is the dominant *Eschara* of the Chalk, but now, for the first time, another form successfully displaces it.

Reticulipora obliqua is very common and occurs in masses. Here again it, for the first time, becomes a really common form.

Heteropora pulchella occurs in colonies, often as large as a brick, and is mostly confined to the lower half of the zone. It is here a very characteristic fossil.

Vincularia disparilis, so common in the upper zones, is among the rarest of fossils here, and its absence is very characteristic, for it is rarely found below this level.

Terebratula semiglobosa is common, but does not reach the abundance and large size so common in the zone of *H. planus*.

* Cotteau, "Ech. de l'Yonne," p. 486, pl. 82, fig. 3.

In the latter zone also *Terebratula carnea* is very abundant and characteristic, and its comparative absence in this zone is a good diagnostic point.

Rhynchonella limbata is a common fossil at the top of this zone at Dover, but it is limited to that situation, and, in the writer's experience, its marked occurrence at this level is confined to the section in question.

Plicatula barroisi, though found in the zones of *Micraster coranguinum* and *Marsupites testudinarius*, is a comparatively rare fossil, and it is not until we reach this zone that it comes in abundantly. Its white colour against the grey marl makes it a conspicuous object.

Zone of Holaster planus.

FROM 200 YARDS NORTH-EAST OF THE LOW LIGHT TO A PERPETUAL SPRING ISSUING FROM THE BASE OF THE CLIFF, NORTH-EAST OF THE WINDLASS IN BANTAM HOLE.

The spring is 150 yards east, on the 6-inch map, from the north-east corner of Fan Hole. This additional measurement is given because Fan Hole, by reason of the great scoop-out at the top of the cliff, can always be located from the shore. The windlass is in a trench, cut from top to bottom of the cliff, and is used by the Coastguards for hauling up material.

This zone is also composed of nodular-chalk, full of organic remains, and very similar in appearance to the zone above it. There are no marly bands, and the flints are frequently spongiform. The upper limit of this zone has been given at the lower of two strong flint-lines, 15 ft. apart, with a band of scattered flints between them. The measurements of the zone are as follows:

From the lower of the two strong flint-lines to the top of the Chalk-Rock	16 ft.
From the top of the Chalk-Rock to its base . . .	9 ft.
From the base of the Chalk-Rock to an open marl-band between two pairs of nodular flint-lines . .	9½ ft.
Total	34½ ft.

The Chalk-Rock itself rises a few yards north-east of the submarine telegraph-cable, between the High and Low Light. This bed has been called Chalk-Rock because of its peculiar lithological character. It is, usually, an intensely hard, cream-coloured limestone. Associated with, and confined to this bed, is often a peculiar gasteropod and cephalopod fauna. Mr. Henry Woods* has written an admirable monograph on the mollusca of

* H. Woods, "The Mollusca of the Chalk-Rock," *Quart. Journ. Geol. Soc.*; vol. lii and liii, February, 1896, and May, 1897.

this bed, and the reader is advised to consult it. Lithologically, however, we have here no true Chalk-Rock, but only a thicker nodular bed, or series of nodular beds, with patches of soft, grey, marly chalk included in it. Green glauconitic grains, and green phosphatic nodules are hardly ever seen, but brown nodules of phosphatic chalk are present in abundance, and are much more frequent than in the zone above. Many of the fossils are met with in the form of brown phosphatic casts. Sponges are very abundant.

It is a matter of opinion whether it is better to take the *H. planus*-zone as low down as the open marl-band between the two pairs of flint-lines, or to the top of the two first flint-lines, above the open marl-band; but the writer has been guided by purely zoological evidence, and for that reason takes the lower level. Between the base of the Chalk-Rock and the open marl-band (that between the two pairs of flint-lines), we find an abundance of *Cyphosoma radiatum* and *Holaster planus* is common. *Micraster* and *Echinocorys* are much less abundant than in the Chalk-Rock, but they begin here. It is the occurrence of these typical urchins of the *H. planus*-zone, together with *Holaster planus* itself, which has determined us to fix the division-line at this point. As for the upper limit of the zone, if collecting means anything, it clearly shows that there is no lithological division between this zone and the one above it. At this upper limit the evidence of *Micraster* is so conclusive that the writer has never had the least difficulty in obtaining a division-line between this zone and the one above it, and the evidence obtained by this one fossil invariably coincides with the disappearance of *Holaster planus*, *Micraster cor-bovis*, and *M. leskei*. There is a curious diminution in the number of *Micraster*, and even of *Echinocorys*, in the space of chalk (about 15 ft.), which forms the transition area between the two zones in question.

We have just over half-a-mile of this zone, all in good condition for collecting, and it is the finest section of the zone with which the writer is acquainted. The gentle dip of the beds permits every foot of it to be worked in succession.

Typical Fossils of the Zone of Holaster planus.

Holaster planus		34½ ft.
Micraster præcursor	of the group form peculiar to this zone . .	
Micraster cor-testudinarium		
Micraster cor-bovis		
Micraster leskei		
Echinocorys vulgaris var. *gibbus*		
Gasteropods and Cephalopods (when present) . .		

Other characteristic fossils are *Pentacrinus*, *Cardiaster ananchytis*, *Cidaris serrifera*, *Cyphosoma radiatum*, *Holaster placenta*, *Serpula ilium*, *Eschara acis*, *Rhynchonella cuvieri*, *R. plicatilis*, *Crania egnabergensis* var. *striata*, *Terebratula carnea*, *T. semiglobosa*, *Terebratulina gracilis*, *Plicatula barroisi*, and *Inoceramus* sp.

There are no zoological divisions in this zone, save where the Chalk-Rock occurs. This bed may exist both zoologically and lithologically; zoologically alone, or lithologically alone; or may be absent in both senses. All these variations have come within the writer's experience. In English sections there is no warrant for the use of a separate *Micraster leskei*-zone.

In this section the Chalk-Rock only exists in the zoological sense, and the peculiar fauna is very rich. If we trace up the dominant fauna of this zone from its base to the bottom of the Chalk-Rock, through the Chalk-Rock, and above it to the junction with the zone above, we find no alteration in the fossils whatever. *Holaster*, *Micraster*, and *Echinocorys* pass through the Chalk-Rock unchanged, and even a very plastic form like *Micraster* pursues its evolution without any deviation. The writer acknowledges the usefulness of a hard, rocky bed in local surveying, but otherwise he regards it as a mere interpolation, in no way affecting the life-history of the zone, either by its presence or absence. Too much importance has been given to this very variable and inconstant bed, and to make it a base-line of the so-called Upper Chalk seems to be particularly lacking in point, as in not a few sections it does not exist at all.

Holaster planus.—A comparison between this well-known species and the less-known *Holaster placenta* has been made on page 309. It never reaches the large size of *Holaster placenta* and differs from it in being taller, in having a well-marked anteal sulcus, and a rounded base. *Holaster placenta*, on the other hand, has little or no anteal sulcus, and has a perfectly flat base, with a sharp-edged ambitus, such as we see in *Holaster trecensis*. The downward range of *Holaster planus*, as far as we have yet traced it, is to the top of the *R. cuvieri*-zone; but it becomes a rare fossil as soon as we pass below the middle-third of the *T. gracilis*-zone.

Holaster placenta is not so abundant in this zone as in that immediately above, but it is a common fossil. Hébert's contention that it is a guide-fossil to the zone of *M. cor-testudinarium* alone may be true in France; but in England the writer has a range for it from the top of the zone of *Rhynchonella cuvieri* to the base of the zone of *Actinocamax quadratus*, the highest and lowest occurrences being of course rare. It is much smaller in the higher and lower zones, and its maximum development, both in size and abundance, is in the zone of *M. cor-testudinarium*.

Micraster cor-bovis is found in both a small and a large form, and varies in length from 50 to 80 mm. It is not common, and broken sections of it in the cliff face are generally mistaken for *Holaster*. The only thing is to pick the fossil out and clean it, as a determination can then be made even from a small portion of the test. The largest examples have been found above the Chalk-Rock. *Micraster leskei* is even a better guide-fossil than *Micraster cor-bovis*, as at Dover its range is practically restricted to the limits of this zone. For the range and description of *Micraster cor-bovis* and *M. leskei* the reader is referred to the paper on *Micraster*.

Echinocorys vulgaris var. *gibbus* is very abundant, and in no way differs from that in the zone above.

Pentacrinus is a fine zonal-guide in every section in this zone in the South of England, as it occurs in abundance, and weathers out well. It is rare in the zone above, and is fairly common in the upper-part of the *T. gracilis*-beds, but its maximum development occurs in this zone.

Cidaris serrifera is still the dominant form in this zone, as in the zone above.

Cyphosoma radiatum reaches its maximum development in this zone, not only in this section, but in all others on the South Coast. It is particularly common at the base, and also in the first 20 ft. of the zone of *Terebratulina gracilis*. Its downward range is to the base of the *T. gracilis*-zone, and it ranges upward as high as the *Belemnitella mucronata*-zone, becoming rarer as we ascend in the zones.

Cardiaster ananchytis is never a common fossil, but is very suggestive of the zone, as only one example has been found in the zone of *M. cor-testudinarium*. It is not confined to the Chalk-Rock.

Serpula ilium is as common here as in the zone above, and the chalk is crowded with them.

Eschara acis is very abundant, and can be picked out of the soft marly pockets in this zone by the score. There are many other forms of Bryozoa found here, but none of them are sufficiently characteristic to record.

Terebratulina gracilis is of frequent occurrence in this zone, but it rarely extends into that immediately above; and the same remark applies to *Rhynchonella cuvieri*.

Terebratula carnea and *T. semiglobosa* are found in unexampled profusion in this zone, especially immediately above the Chalk-Rock, where the largest examples are found. The *Terebratula carnea* is not the true form of the *Belemnitella mucronata*-beds at Meudon, but is much broader, and with a larger foramen. Wherever we have worked this zone, there have we found this broad form in a profusion which makes it one of the most easily recognised guide-fossils.

Rhynchonella plicatilis is also abundant at the same level, and reaches a large size. The var. *octoplicata* is the commoner form.

Crania egnabergensis var. *striata* may almost be called a common fossil in this zone, in the South of England, and it has an unbroken range from the zone of *T. gracilis* to that of *A. quadratus*; being, however, only really common again in the last-named zone.

Inoceramus brongniarti is found in this zone at Dover, and extends to the zones immediately above and below it, but in reduced numbers. It is commoner here than in Sussex. *Inoceramus* sp.: This is figured in Mr. Woods' paper (pl. xxvii, figs. 14 and 15), and is abundant at Dover in this zone. It occurs occasionally in the zone above and the zone below, but it is only abundant in the *H. planus*-zone. It is not confined to the Dover section.

Plicatula barroisi is very abundant in this zone and the one above, and we have never met with it so abundantly as at Dover, where fifty examples could easily be found in a day's collecting. This fossil is not well-known, and the reader is referred to Mr. Henry Woods'* paper on the Chalk-Rock for an accessible figure. We have found it from the base of the *T. gracilis*-zone to the top of the *Marsupites*-zone.

Pleurotomaria perspectiva and *Turbo gemmatus* are the two gasteropods upon which we can rely, even when the Chalk-Rock fauna is not represented. The former has been found in every section of this zone which the writer has worked, though it is never an abundant form. A *Pleurotomaria*, apparently of the same species, ranges from the zone of *R. cuvieri* to that of *A. quadratus*, but it is always rare.

It has been suggested that the zones of *H. planus* and *M. cor-testudinarium* should be merged into one, on the ground that they cannot be separated in the field in inland sections. We can only say that we have yet to find a section in either zone which cannot be readily assigned to its proper horizon, and that on purely zoological data. This does not apply to cliff-sections only, but to ill-exposed inland sections. We are quite aware that *Holaster planus* is uneven in its distribution within its own zone, and cannot be relied upon to be present in quantity. One magnificently air-weathered bluff in South Dorset gave an illustration of this, as not a single *Holaster planus* could be found; so we relied upon *Micraster*, *Terebratula carnea*, and *Pentacrinus* for our determination, and obtained it with ease. Close by was another bluff, which was full of *Holaster planus*, as well as the other guide-fossils. *Micraster* is always sufficiently common to be a ready means of determination, and it is infinitely more abundant in these two beds than in any others. For our own part, we desire no easier or readier means of determination.

* *Op. cit.*, pl. xxvii, figs. 18 and 19.

Whether *Holaster planus* is a suitable name-fossil for this zone has often been discussed, but we very much doubt if a better can be found. We know perfectly well that its range is not limited to this zone any more than are the fossils which give their names to the zones of *R. cuvieri*, *T. gracilis*, *M. cor-testudinarium* or *M. cor-anguinum*, restricted in their range to the zones mentioned. We are never forced to rely upon one fossil for obtaining a zonal determination, and we know that, linked with the name-fossil, which here attains its maximum development, is a group of associated forms, such as *Micraster cor-bovis*, *M. leskei*, *M. præcursor* and *M. cor-testudinarium* (of the form peculiar to this zone), upon which we can rely, if the name-fossil be not well represented. It is this association of life-forms, and their variation, as we trace them, zone by zone, which gives zonal geology its value. Neither *Micraster cor-bovis* nor *M. leskei* is restricted to this zone, nor can we rely upon the cephalopods and gasteropods, as they are not always present. The only fossils which are alike abundant, and definitely limited to this zone, are the groups of *Micraster præcursor* and *M. cor-testudinarium*, of the peculiar facies found at this horizon. Good, however, as are these groups for zonal determination, they are *not a separate species*, but only a zonal variation of a far-extending group. Therefore they cannot be used as a name-fossil, and we can see no better course than to adhere to the old title of *Holaster planus* as the name-fossil for this zone.

Zone of Terebratulina gracilis.

FROM THE SPRING ISSUING AT THE BASE OF THE CLIFF TO THE CASTLE JETTY. ALSO THE SECTION IN THE CLIFFS WEST OF DOVER.

At the time of writing, the Dover Harbour extension works are in progress, and soon there will be no cliffs to collect from south-west of Langdon Stairs. From a geological point of view this is a pity, as there is no continuous section in this zone of such extent and in such good order for working. These beds consist of a hard, dead-white chalk, not very rich in fossils, with numerous marly veins and seams; hard, white, nodular chalk bands, and some irregular lines of flint. The chalk looks much softer than it is, for it is hard to cut with a chisel, and fossils from it are difficult to clean, owing to the adherent nature of the marl. The marl-bands are a characteristic feature of this chalk in all the South of England sections. The flints are black and compact, with a thin white cortex.

The beds in this zone, as divided by marl-bands, have no zoological value, the fauna being the same throughout. The

marl-bands are useful, however, in tracing the rise of the beds towards Dover. They are as follows :

From first open marl-band, between two pairs of flint-lines, to second marl-band	16 ft.
From second open marl-band to the third . . .	15 ft.
From third open marl-band to the fourth (the 4-ft.-band) .	4 ft.
From the fourth open marl-band to shore at Castle Jetty	56 ft.

This gives a thickness for this zone as exposed in the East Cliffs, of 91 ft. The measurement has been checked by Captain Gordon McDakin with an aneroid, at the tunnel leading from Dover to the East Cliffs, and found to be correct.

On the west side of Dover this zone can be well studied in the zig-zags at the Channel-Tunnel works, and at Lydden Spout, and from fallen blocks on the shore. The dip of the beds is much the same as in the East Cliffs. It is impossible to join-on the sections in the two cliffs, as we have no lithological guide which we can carry from one side to the other. The 4-ft.-band rises in Langdon Bay and reaches the level of the Dover end of the East Cliff Tunnel. It is seen on the low bluff at the west end of Castle Cliff, and it can be traced into the bluff under the Drop Redoubt. There we lose it, and no trace of it can be found in Shakespeare's Cliff.

Some of this zone is, therefore, missing.

In the West Cliffs we have	70 ft.
In the East Cliffs we have	91 ft.
Total	161 (as exposed)

Typical Fossils of the Zone of Terebratulina gracilis.

Terebratulina gracilis	161 ft.
Micraster cor-bovis	
Inoceramus labiatus	

Other characteristic fossils are *Pentacrinus*, *Discoidea dixoni*, *Holaster planus*, *H. placenta*, *Hemiaster minimus*, and *Rhynchonella cuvieri*.

This zone cannot well be subdivided, as the three dominant forms are found from bottom to top of the zone.

Terebratulina gracilis reaches its maximum development in this bed, but it ranges from the zone of *R. cuvieri* to that of *M. cor-testudinarium*.

Micraster cor-bovis is by no means rare in this zone at Dover, especially at the upper limit. Since the paper on *Micraster* was written, General Cockburn has found two examples of the smaller form of this urchin in the base of this zone in the West Cliffs. This gives a new record for the section. General Cockburn possesses the finest collection of this interesting urchin in existence.

Sponges are found in profusion in this bed, and *Guettardia stellata* and *Craticularia fittoni* reach a size and importance unknown in any other zone, or in any other section of this zone. We have measured a *Guettardia* 14 inches across, and have a mass of *Craticularia* a foot square. *Ventriculites*, *Cephalites*, and *Plocoscyphia* are equally abundant, and not infrequently we find the last-named with its outer wall intact. We know of no section so rich in *Cephalites* as this.

Pentacrinus is common at the top of this zone, but the large size of the ossicles is lost when we approach the base of the zone.

The range of *Holaster planus* and *H. placenta* have already been given on pp. 309 and 312.

Discoidea dixoni is by no means confined to the zone of *R. cuvieri*, but may be found from base to top of the zone of *T. gracilis*, though it is not very common, save in certain localities. It is sometimes found in the *H. planus*-zone.

Hemiaster minimus, though not so common as in the zone below, is well represented, and ranges up as high as the *M. cor-testudinarium* zone. At Beer Head, Devonshire, it is quite a common fossil in the *T. gracilis*-beds, and runs to a larger size than anywhere else.

Rhynchonella cuvieri is a common fossil in this zone everywhere, and in some localities is quite as abundant as in its own zone.

Inoceramus cuvieri is very abundant, and reaches a great size. The writer found one example 3 ft. across, and removed the hinge, which is as thick as one's wrist.

West Cliffs, Dover.

Zone of Rhynchonella cuvieri.

This bed can be studied in the zig-zags, and rich collecting may be obtained from the fallen blocks on the shore. It is a hard, dead-white chalk, veined with marl, and interspersed with hard nodular bands of chalk. At the base is the "grit-bed," 32 ft. thick, intensely hard and ringing to the hammer; it is rough with fragments of shells, chiefly *Inoceramus labiatus*.

The hard "grit-bed" is very prominent in the cliffs, based as it is by the soft *Actinocamax plenus*-marls, which fall away from it, leaving the sharp overhanging edge of the "grit band." By this means the bed can be traced in the cliffs to Folkestone.

The top of this zone may be fixed by a flint-line 70 ft. above the base of the grit-bed, when the hard chalk passes into the more marly, and comparatively softer, chalk of the zone above. This division is, however, purely arbitrary, and only used for convenience, and the zoological break is as imperceptible as the lithological.

The Broad Zoological Divisions of the Zone of Rhynchonella cuvieri.

Rhynchonella cuvieri *Inoceramus labiatus* *Discoidea dixoni*	throughout the zone . .	70 ft.
Cardiaster pygmæus *Echinoconus subrotundus* *Echinoconus castanea* *Salenia granulosa* *Glyphocyphus radiatus* *Cidaris hirudo* *Ammonites peramplus*	in the grit-bed = 32 ft. .	

Rhynchonella cuvieri is at its maximum development in this zone. It ranges upward to the *M. cor-testudinarium*-zone, where it is rare.

Inoceramus labiatus has the same range, becoming rarer also as it gets higher; but it is always fairly common. *Inoceramus cuvieri* is as rare as *Inoceramus labiatus* is common, and is, therefore, useful in separating these two zones.

Discoidea dixoni is very common in the grit-bed, and passes up, with varying frequency, to the top of the *Terebratulina gracilis*-beds. Occasional specimens are found as high as the zone of *Holaster planus*. It is notably common in the *T. gracilis*-beds at Beer Head, Devonshire. General Cockburn has found several specimens with the anal plates *in situ*.

Cardiaster pygmæus is very common in the "grit-bed" at Dover. It rapidly decreases in frequency as we ascend the zone and is a rare fossil in the zone of *T. gracilis* except at Beer Head. We have never met it at a higher level, save in one very large example from the base of the *M. cor-testudinarium*-zone at Dover. Dr. Gregory referred the solitary specimen to this species.

Echinoconus subrotundus and *E. castanea* are found abundantly in the upper part of the "grit-bed," and scattered examples of the former are found throughout the zone, and even in the *T. gracilis*-beds. *Echinoconus castanea* has a more restricted range, and is rare beyond the "grit-bed." At Dover a very small form of this is common, but we have not met with it elsewhere.

Salenia granulosa ranges as high as the zone of *Actinocamax quadratus*, but its maximum development is in the "grit-bed." The only other zone where it occurs with a similar frequency is in that of *Holaster planus*. It is comparatively rare in the zones of *Micraster cor-testudinarium* and *Marsupites testudinarius*, but it again comes in rather strongly in the zone of *A. quadratus*.

Glyphocyphus radiatus is always a rare fossil, but we have invariably found it in the lower part of the zone in the sections which we have worked. Its range appears to be much restricted, and it is thus a useful zonal guide.

Cidaris hirudo does not occur with us in the same abundance as it does in France in the zone of *T. gracilis*. Here it ranges from the zone of *Rhynchonella cuvieri* to that of *Belemnitella mucronata*. It is a common form at Dover, Beachy Head, and Beer Head, especially in the last locality, and is more frequently found in the zone of *R. cuvieri* than in that of *T. gracilis*.

Radiolites mortoni is not uncommon in this zone at Dover, and it extends down as far as the Chalk-Marl. We have not met with it in the zone of *T. gracilis*, nor did we find it in the *R. cuvieri*-zone at Beachy Head. The only other occurrence of *Radiolites* which we have to mention is, curiously enough, a solitary example in the *Marsupites*-zone at Margate.

Terebratula semiglobosa is a useful guide-fossil in this zone. In the true type of *Terebratula semiglobosa* the frontal margin is undulated; but in the forms found in this zone, and to a less extent in that of *Terebratulina gracilis*, it is straight. By this we do not mean that both frontal and lateral margins are straight, as in *Terebratula carnea*, but that the central biplication is absent. The shell is also much narrower and very tumid. This is the form which we understand as *Terebratula semiglobosa* var. *albensis*. We know of no other zone where this shape occurs with such frequency.

Whether the zones of *R. cuvieri* and *T. gracilis* should be merged in one is a moot point. From a purely zoological point of view we are of opinion that it is better to separate them, partly because there is a certain difference in the fauna of the two zones, and partly from force of custom. Still there is less need for separation here than in any two other consecutive zones. If they were merged, Barrois' title of *Inoceramus labiatus* would do as well as any, as the shell occurs in great abundance, and is constant throughout the two zones. If they are to be separated it is probable that *Rhynchonella cuvieri* is the best name-fossil for the lower zone, as it can be removed so much more readily for determination than can *Inoceramus*, and it is so much better preserved. The disadvantage of *Terebratulina gracilis* as a name-fossil is that, in wave-worn sections, it is very hard to find, as it is destroyed at once. In air-weathered sections, on the other hand, it is an excellent guide, as it is very abundant, and shows up well. In any case the zone of *T. gracilis* is a very colourless one.

An ideal arrangement would be to have an echinoid as the name-fossil for both zones, or to have a separate urchin for each zone. Let us see how it works out for the *R. cuvieri*-zone. For Dover and Beer Head *Cardiaster pygmæus* would do well, because it is so abundant; but it would be useless for Dorset and Beachy Head, as it is so rare there. In the same way *Discoidea dixoni* would do for Dorset, Dover, and Beer Head, but not for Beachy Head.

In the case of the *T. gracilis*-zone, *Discoidea dixoni* would do fairly well all round, but it seems absurd to give it as a name-fossil

when its maximum development is in the zone below. *Micraster cor-bovis*, again, though it is fairly abundant at Dover and Beer Head, is too rare in Dorset and at Beachy Head to be a useful name-fossil. Besides, the test is so thin that complete specimens are rare, and it is not everyone who would have the knowledge to determine the form from fragments. On the whole we prefer the division and title of the zones as herein given.

Before leaving the Dover section it will be well to give the beds in succession, from the zone of *T. gracilis* to that of *M. cor-anguinum*, as seen from below upwards, in the zig-zag at Langdon Stairs.

Section in Langdon Stairs.

Below the lowest slope there are rough steps cut in the cliff, which are in the zone of *T. gracilis*, with the second open marl-band showing.

1st slope.—At the bottom of this slope is seen the first open marl-band, with the two pairs of flint bands above and below it, marking the junction of the *T. gracilis*- and *H. planus*-zones. The rest of the slope is in the zone of *H. planus*, and at the top of the slope, in the corner where it joins the second slope, is the junction of the zones of *H. planus* and *Micraster cor-testudinarium*.

2nd slope.—All of this is in the zone of *M. cor-testudinarium*.

3rd slope.—All of this is in the zone of *M. cor-testudinarium*, and the thin *M. cor-testudinarium*-tabular occurs in the lower part of the slope.

4th slope.—All this is in the zone of *M. cor-testudinarium*.

5th slope.—Shows the junction of the zones of *M. cor-testudinarium* and *M. cor-anguinum*; the basal *M. cor-anguinum*-tabular is one-fourth of the way down from the top of the slope.

6th slope.—All of this is in the zone of *M. cor-anguinum*. The measurements taken of the beds on the shore were checked here, and agreed in all instances.

Measurements of the Zones in the Kent Coast.

The approximate measurements of the zones in the White Chalk of the coast of Kent are as follows:

		ft.	
Zone of	*Marsupites testudinarius* .	116	(as exposed)
„	*Micraster cor-anguinum* .	280	
„	*Micraster cor-testudinarium*	56	
„	*Holaster planus* . .	$34\frac{1}{2}$	
„	*Terebratulina gracilis* .	161	(as exposed)
„	*Rhynchonella cuvieri* . .	70	
	Total . . .	$717\frac{1}{2}$	

PART II

COAST OF SUSSEX.

D. EASTBOURNE TO THE CUCKMERE.

Barrois' admirable work is the only one to consult on this coast. The section is not an easy one to read, and a day would be well spent in walking from Eastbourne to Birling Gap, so as to get a comprehensive idea of the beds before collecting. A good spring is found on the reefs a little east of Belle Tout, and another under it.

We see no more coast-sections in the Chalk, after we pass Folkestone, until we reach Eastbourne. The Grey Chalk can be reached from the west end of the Parade, and time will not be wasted by walking along the shore to Beachy Head, as a magnificent section of *Actinocamax plenus*-marls is exposed, based by the zone of *Holaster subglobosus*, and capped by that of *Rhynchonella cuvieri*. One passes all the beds in succession down to the Upper Greensand. Before doing this it would be well to examine the old quarry called Holywell, where there is a pumping-station to catch the water thrown out by the *A. plenus*-marls.

In Holywell we have a fine section of *Rhynchonella cuvieri* and *Terebratulina gracilis*-zones, and we have a chance, by taking in the cliffs west of the main quarry, of obtaining a complete thickness of the former zone, which here measures 100 ft. A quicker way to reach Beachy Head is to walk along the cliffs to Cow Gap, which is merely a narrow cliff-path to the shore, and then to descend to the beach, which lands us within 1,200 yards of the main section. It should be remembered that, after we pass Cow Gap, there is no way up from the shore until we reach Birling Gap—a distance of 3½ miles, and very heavy walking all the way.

By descending to the shore at Cow Gap a complete exposure of Chloritic Marl, and the reefs in the Upper Greensand may be seen. In the cliffs north of "Falling Sands" we have a good section in Chalk Marl, *H. subglobosus*-zone and *A. plenus*-marl, capped by the zone of *R. cuvieri*. There may be some of the *T. gracilis*-zone at the top, but the falls only give evidence of a *Rhynchonella cuvieri* fauna.

The reefs west of "Falling Sands" show, in proper succession, *Rhynchonella cuvieri* and *H. subglobosus*-zones, Chalk Marl, Chloritic Marl, and Upper Greensand.

This brings us to a point on the shore corresponding to the Watch House on the top of the cliff, which is the east end of a

large and ancient turf-clad fall, known locally as "Gun Gardens," from the fact that it was once cultivated, and that a small battery was there. Gun Gardens is east of "The Charleses," on the 6-inch map, which is a local name for semi-detached pinnacles at the top of the cliff in *M. cor-anguinum*-chalk. At the east corner of Gun Gardens, under the Watch House, we have a fine section from the zone of *Holaster subglobosus* to that of *Micraster cor-testudinarium*; and at the west corner of Gun Gardens is another fine sheer surface, which shows the series from the zone of *Rhynchonella cuvieri* to the base of the *M. cor-anguinum*-zone, with the thick *M. cor-anguinum* flint tabular passing out at the top of the cliff.

In Gun Gardens itself, half-way up the slope, we see a white chalk bluff (marked on the 6-inch map), the lower part being in the *R. cuvieri*-zone, and the summit in that of *T. gracilis*, the two zones being roughly divided by a marl-band. This bluff is easily accessible, and is well worth the climb, as it is the only well-weathered surface in the *R. cuvieri*-zone at Beachy Head. It may be mentioned that Gun Gardens is the place where people climb down from the top of the cliff, and where many lives have been lost in the attempt.

At the west angle of Gun Gardens we see the actual junction of the zones of *R. cuvieri* and *T. gracilis*, marked by the lowest marl-band. This is not on the shore-line, but on the grass slope. The actual junction on the shore-line is seen 293 yards west of the west corner of Gun Gardens, and is marked by the marl-band already mentioned. The thickness is practically 100 ft., the same as at Holywell. These beds are on the Beachy Head anticline, and are dipping strongly to the west.

Passing west for 150 yards we come to a point on the shore which is a little west of the figure "364," on the 6-inch map, on the path at the top of the cliff. We here see the junction of the zones of *T. gracilis* and *H. planus*, and it is very easy to identify this, on the shore-line, by the contact of the flintless *T. gracilis* chalk, and the flinty *H. planus*-chalk. This gives us a measurement of 170 ft. for the zone of *T. gracilis*.

Going further west, we reach, at a spot a little east of the letter *t* in Ford's Point, on the 6-inch map, the junction of the zones of *H. planus* and *M. cor-testudinarium*. This is roughly indicated in the cliff-face by a vertical fissure, extending from top to bottom, and filled in with ferruginous material. Another way to pick up the junction of the zones of *H. planus* and *M. cor-testudinarium* is to measure 240 ft. west along the shore-line, from where the top of the flintless *T. gracilis*-zone rises from the sand. These are useful guides, but the only legitimate way is to get the actual junction from zoological data, and this can only be done by collecting foot by foot. Owing to the zone of *H. planus* being on the sharp rise of the anticline,

we get a very short section of it. The thickness of this zone is 48 ft.

From this point we walk westward for a mile, the dip of the beds being now comparatively slight, until we come within 200 yards of Belle Tout, where we see the junction of the zones of *M. cor-testudinarium* and *M. cor-anguinum*. The approximate junction is fixed by a thin flint tabular band, which rises from the sand at this point, about 60 ft. below the very thick tabular band, which is obviously in the *M. cor-anguinum*-zone.

The position of Belle Tout Light can be ascertained by finding "Darby's Hole" at the bottom of the cliff. This is a double cave in a vertical fissure; the thick *M. cor-anguinum* tabular band passes between the two caves, and a wire rope hangs down them. This cave is about 50 yards west of the flag-staff, which can be seen at low water by walking out on the reef. The Lighthouse itself is too far back to be seen.

Two worked caves (marked on the 6-inch map) are found between this cave and Birling Gap; and 100 yards west of the second, and most westerly of these caves, is seen the strong *M. cor-anguinum*-tabular rising from the shore, and passing 5 ft. under the second cave.

This is the same strong tabular in the *M cor-anguinum*-zone, which we noted before, as it passed out at the top of the cliff on the west side of Gun Gardens. This strong tabular can be traced on the reef some 200 yards east of Birling Gap. In 1898-9, it formed a thick sheet on the top of the reefs, but is gradually being broken up by the waves. Fifty feet above the thick tabular in the cliff is seen another and much thinner tabular, and 15 ft. above that, is a very indistinct yellow sponge band. It is important to notice this, as Barrois lays great stress on it in the "Seven Sisters" Section, and it will be referred to later on.

Zone of Rhynchonella cuvieri.

FROM THE EAST CORNER OF GUN GARDENS, WHERE THE JUNCTION OF THE ZONES OF *A. PLENUS* AND *R. CUVIERI* ARE SEEN, SOME 30FT. ABOVE THE SHORE LINE, TO A POINT 293 YARDS WEST OF THE WEST CORNER OF GUN GARDENS.

It is impossible to give a better guide than this, for there is nothing on the shore-line, or the top of the cliff, to give a clearer indication. The chalk is of the same nature as that at Dover, save that the "grit-bed" is ill-developed. There are no flints, and the iron-pyrites is the same as that seen in the Grey Chalk. This is a very poor section from the collector's point of view, as the chalk is not nearly so rich as that at Dover, and, in addition, it is so pounded by the shingle that all fossils are smashed off as soon as they weather out.

This last-mentioned tabular flint-line will be called the *M. cor-testudinarium*-tabular, as it approximately marks the zoological break between this zone and the one above it. No attempt is made to correlate it with the *M. cor-testudinarium*-tabular at Dover, as the lithological conditions vary so much in the two sections. This *M. cor-testudinarium*-tabular is situated 200 yards east of Belle Tout, at which point it rises from the beach, and below it are seen three strongly-marked yellow nodular bands. Below the *M. cor-testudinarium*-tabular the typical fossils of this zone come in with a rush, and though there are several yellow nodular bands above it, the fossils are essentially those of a basal *Micraster cor-anguinum* fauna. This is a marked contrast to Dover, where the lithological and zoological break coincides, and is only another instance where lithology fails us, and where rigid zonal collecting can alone help us out of the difficulty.

Typical Fossils of the Zone of Micraster cor-testudinarium.

Micraster præcursor } of group-form peculiar to this zone
M. cor-testudinarium }
Echinocorys vulgaris var. *gibbus*

As at Dover, there are no zoological divisions in this zone, the dominant forms being continuous throughout. *Micraster* is our only reliable guide, and the essential features of the test, which were so helpful at Dover, are equally reliable and constant here. The proportion of the broad *Micraster cor-testudinarium* forms is rather larger than at Dover, and the percentage of occurrence of the "sub-divided" ambulacral area is also larger than at Dover, and is quite characteristic of this zone. *Echinocorys vulgaris* var. *gibbus* is quite as common as at Dover, and the unfailing abundance and uniformity of this fossil, in the zone, is constant in all the sections which we have worked. *Echinoconus conicus* and *Cyphosoma königi* were found here, but not at Dover. They are rare fossils in this zone. The spines of *Cidaris clavigera* are, if anything, in greater profusion than in the zone below, and while *Cidaris serrifera* is still a characteristic form, it is not so abundant as the former.

Terebratula semiglobosa is not so common here as at Dover, save at the base of the zone; but in the same zone at Seaford Head it is quite as common.

Rhynchonella limbata, so common at the top of the zone at Dover, is here represented by a solitary example. The same small form of *Lima hoperi* is common to both sections. *Holaster placenta* is common, but not so abundant as at Dover, and, as has been remarked before, small examples of this fossil have been

mistaken for *Holaster planus*, and for a thin-tested *Echinocorys* which is found at this level. The Bryozoa in the section are abundant, and much resemble the Dover and the Chatham forms, as *Eschara acis*, *Recticulipora obliqua*, *Homœosolen ramulosum*, and *Semicytis rugosa* are all abundant. On the other hand, *Pavolunulites*, *Micropora intricata*, and *Multelea* which are common here, are rare at Dover; while *Heteropora pulchella*, so common at Dover, is practically absent here. No gasteropods have been found. *Plicatula barroisi* is but poorly represented, as compared with Dover. Sponges are poor in this zone at Beachy Head, with the exception of a small form of *Pharetrospongia strahani*, which is very abundant, both in this zone and in the base of the *M. cor-anguinum*-zone, and is equally abundant at Seaford Head.

Zone of Micraster cor-anguinum.

FROM A POINT 200 YARDS EAST OF BELLE TOUT TO THE CUCKMERE.

Directly we pass above the *M. cor-testudinarium*-tabular, we come into a chalk with several yellow nodular bands, not so well-marked as those below the tabular, but still of the same nature. Lithologically, they would appear to belong to the *M. cor-testudinarium*-zone, but zoologically they must be included in the zone of *M. cor-anguinum*, as the fossils are scanty and belong to the higher zone. Above these nodular bands the chalk is of the typical *Micraster cor-anguinum* nature. The flints come in at regular intervals. Barrois says that they are black, with a thick, zoned cortex. This is true in certain situations, but under the Seven Sisters they frequently have a very thin white cortex.

Passing westward from the junction of the zones of *M. cor-testudinarium* and *M. cor-anguinum*, we come to Belle Tout, 50 yards west of which is the double vertical cave, with the wire rope, called Darby's Hole. Intersecting this double cave is the strong *M. cor-anguinum*-tabular, rising from the shore 100 yards west of the first of two worked caves, which are seen between this point and Birling Gap, both being marked on the 6-inch map. The thick tabular passes 5 ft. under the floor of this cave. About 50 ft. above this strong tabular is another thinner one, with a yellow sponge-bed 15 ft. above it, here very badly indicated. This is the bed which must have induced Barrois to put so much of the upper part of the cliffs into the *Marsupites*-zone. He gives only a thickness of 120 ft. for the zone of *Micraster cor-anguinum*, which would appear, on the face of it, to be an inadequate estimate of this bed in the south of England. Barrois evidently looked upon this tabular flint-line, with the sponge-bed

15 ft. above it, as analogous to the "Whitaker 3-inch" tabular and the "Barrois sponge-bed" in Thanet. These will, therefore, be alluded to as the "spurious tabular and sponge-bed," so as to avoid confusion. Had this been a correct deduction, all the chalk above this sponge-bed would have been in the *Marsupites*-zone, and there would have been room for some of the *Actinocamax quadratus*-zone as well. We know, however, that in this section the sponge-bed is only about 120 ft. above the top of the *M. cor-testudinarium*-zone, so we must see if there is any way to estimate the normal thickness of the *M. cor-anguinum*-zone, and at the same time to establish the existence of the *Marsupites*-chalk. The only way to do this will be to collect along the whole exposure, and to examine the top of the cliffs as well. In point of fact, there are no bands in the section comparable to the "Whitaker 3-inch tabular," and the "Barrois sponge-bed" of Thanet.

Fortunately, the fine section under the Seven Sisters gives us the clue to the base of the *Marsupites*-zone, and Seaford Head settles the whole succession of beds, for we get a complete section there from the zone of *M. cor-testudinarium* to that of *Actinocamax quadratus*.

It will be seen that this identification by Barrois of the "spurious tabular and sponge-bed" with the same guide-beds in Thanet, vitiates the whole of his section from Belle Tout to Brighton.

On either side of Birling Gap we see the "spurious tabular and sponge-bed" half-way up the cliff, and here, as we pass further westward, the sponge bed is very clear. These bands dip to the west until, at Crowlink Coastguard Station, the flint-line is level with the beach; but from that point the bands steadily rise again, and very soon the sponge-bed dies out. In these lower cliffs we have a better chance of studying the beds in the upper part of the cliff, and we notice that, as at Beachy Head and Seaford Head, the flint-lines space out in the upper third of the cliff. If we view the "Sisters" from either side we notice that the tint of the chalk in the highest "Sisters" is of a greyer colour, and that this discoloration corresponds with the upper of two strong nodular flint-lines, 9 ft. apart, and that these two flint-lines generally pass out of the cliff in the hollows between the highest "Sisters." The importance of this observation will be seen when we come to trace the same two flint-lines in Seaford Head, for we find that *Uintacrinus*-chalk is there apparently limited below by the upper of these two flint-lines, 9 ft. apart.

It is clear that we have a chance of finding some portion of the *Marsupites*-zone at the tops of the highest "Sisters." In 1898 we found at the summit of the first and fourth "Sisters" (counting from the Cuckmere), *Uintacrinus*, the nipple-shaped head of *Bourgueticrinus* and *Echinocorys vulgaris* var. *pyramidatus*. This gave us our position at once. These fossils were obtained in little

bare patches, where the turf had been denuded at the cliff edge. But for these providential little weatherings we should never have found these guide-fossils, as there was no fall of cliff from the top, and the rolled blocks on the shore gave no indication of *Marsupites*-zone whatever, though they were searched for evidence. In November, 1899, however, we found a fall under the third "Sister," capped by turf. This contained *Uintacrinus* in abundance, and we again found the same fossils as before at the top of the cliff, together with *Terebratulina rowei* and *Serpula turbinella*; and what was of even greater interest, on the first and highest "Sister," Mr. C. W. Andrews, who was with us, found two *Marsupites* plates. This does not of necessity mean that we have any thickness of *Marsupites*-band, but merely that the *Marsupites*-band and the *Uintacrinus*-band blend here.

There are only two places in the section, between Beachy Head and Birling Gap, where there could possibly be a cap of *Marsupites*-chalk. One place is half a mile west of "the Charleses," and the other at Belle Tout. We have made repeated search in all fallen chalk from the cliff-top at these situations, but no characteristic fossil has been found; nor did examination of the little turf-weatherings at the top of the cliff yield any better result.

There is a way up at Crowlink Coastguard Station, which in 1898 was by no means easy, and in 1899 was inaccessible, except by a ladder.

Typical Fossils of the Zone of Micraster cor-anguinum.

Micraster cor-anguinum	of form peculiar to this zone.	upper three-fourths.	242 ft.
Echinocorys vulgaris			
Echinoconus conicus			
Epiaster gibbus			
Micraster præcursor	of group form peculiar to this zone.	lower fourth.	
M. cor-testudinarium			
Inoceramus involutus			

For other characteristic fossils, and for the description of them, see p. 301. A working knowledge of *Micraster* is doubly important here, as both at Beachy Head and at Seaford Head, we can only fix the junction of this zone with that of *M. cor-testudinarium* by this means. *Inoceramus involutus* is even rarer here than at Dover. In the lower part of this zone, both at Beachy Head and at Seaford Head, we find numerous examples of a small form of *Pharetrospongia strahani* and of *Multelea*, and both these extend into the zone below. Otherwise there is nothing in which this section differs from any other in the same zone. *Echinoconus conicus* is rarer in this zone in Sussex than in Kent.

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bare patches, where the turf had been denuded at the cliff edge. But for these providential little weatherings we should never have found these guide-fossils, as there was no fall of cliff from the top, and the rolled blocks on the shore gave no indication of *Marsupites*-zone whatever, though they were searched for evidence. In November, 1899, however, we found a fall under the third "Sister," capped by turf. This contained *Uintacrinus* in abundance, and we again found the same fossils as before at the top of the cliff, together with *Terebratulina rowei* and *Serpula turbinella*; and what was of even greater interest, on the first and highest "Sister," Mr. C. W. Andrews, who was with us, found two *Marsupites* plates. This does not of necessity mean that we have any thickness of *Marsupites*-band, but merely that the *Marsupites*-band and the *Uintacrinus*-band blend here.

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E. THE CUCKMERE TO SEAFORD HEAD.

On the western side of the Cuckmere are low cliffs of a dirty yellow colour, but west of Hope Gap they rapidly rise, and form a very fine section. From the Cuckmere, to an oblique fissure-cave under the *Castrum*, the bulk of the cliff is in the *M. cor-testudinarium*-zone, a distance of $1\frac{1}{4}$ miles in this one zone. The oblique fissure-cave is an important feature, as it marks the actual junction of the zones of *M. cor-testudinarium* and *M. cor-anguinum*. At Beachy Head (200 yards east of Belle Tout) we are able to take a tabular flint-bed as the division line, but it does not exist here, and we choose in its place a closed marl-seam, which rises from the shore on the eastern side of the fissure-cave. This seam is constant throughout the section and is very easily traced, as the chalk often falls away below it, leaving a sharply-cut overhanging ledge. The fissure itself extends half-way up the cliff, and is iron-stained at the top, where it is intersected by the strong *M. cor-anguinum*-tabular, here 60 ft. above the beach, and is equivalent to the strong tabular in the same position at Belle Tout. This *M. cor-testudinarium*-chalk is deceptive in appearance, as it does not weather out in hard rugged knobs as at Dover and elsewhere, and passing along it in a boat, it was impossible to assign it to this zone from general appearances. The lithological features differ greatly from those at Beachy Head, and both the *M. cor-testudinarium*-tabular, and the "spurious tabular and sponge bed," are wanting. This is a good example of lithological features failing one in a restricted area. At Further Point the beds begin to show evidence of a strong dip to the west, and, by the time that we reach Seaford Head, they are inclined at an angle of about 10 deg.

Passing a little further west of the oblique fissure-cave, we trace the dip of the strong *M. cor-anguinum*-tabular to the shore, below the west side of the *Castrum*. Still passing westward we reach the point where two strong nodular flint-lines sink to the shore. These are clearly the same two flint-lines, 9 ft. apart, which we saw intersecting the bases of the highest of the "Sisters"; so it is probable that we are nearing the junction with the *Marsupites*-chalk. The only thing to do is to fix our division line by collecting. We accordingly begin at the upper of these two flint-lines, 9 ft. apart, and work eastward. We find no trace whatever of *Uintacrinus*; so we retrace our steps and start from the same point and work westward.

At once we find *Uintacrinus*. This gives us our junction line, and so that others may be spared the labour which we had in finding it, we give a measurement from the stone groyne at the east end of Seaford Esplanade, to the upper of two strong flint-lines, 9 ft. apart. We took a straight line along the beach, and this gave us 760 ft., from one point to another. The thickness of

the *M. cor-anguinum*-zone from this point to the marl-seam at the oblique fissure-cave was 242 ft. The next thing to do is to find *Marsupites* itself. At this juncture, it may be well to say that we went over this very area in the section most carefully in 1898, and failed to find a single *Uintacrinus* or *Marsupites* plate. This was due to the fact that every fossil is smashed by the shingle as soon as it weathers out. This time we determined to miss nothing, so we removed every piece of calcite from the cliff face and cleaned it. By this means we got all the evidence which we required. For 28 ft. 9 in. above the upper of two strong flint-lines, 9 ft. apart, we got *Uintacrinus*; and for 48 ft. 9 in. above the *Uintacrinus*-chalk we collected *Marsupites*. Then came a space of about 20 ft. in which we got no *Marsupites* and no *Cardiaster pillula*, but in which the *Echinocorys vulgaris* var. *pyramidatus* began to blend with the var. *gibbus*, and where *Rhynchonella plicatilis* was common. Wherever we have met with a junction between the two zones of *Marsupites* and *Actinocamax quadratus* we have found the same hiatus between *Marsupites* plates and *Cardiaster pillula*, and the blending of the associated guide-fossils. *Cardiaster pillula* invariably extends to the extreme base of the *Actinocamax quadratus*-zone, and we always fix the lower limit of this zone by its presence. The actual junction of the zones of *Marsupites* and *A. quadratus* can here be fixed by an open marl-band, 31 ft. above another open marl-band, and 470 ft. in a straight line along the beach to the stone groyne before mentioned.

We can now fix with certainty the upper and lower limits of our *Marsupites*-zone, for we know that *Marsupites* plates are not found above the second marl-band, and that *Uintacrinus* is not found below the upper of the two strong flint-lines, 9 ft. apart. Further observations may increase the downward measurement of the *Uintacrinus*-band, but not its upper limit; for we got a close contact between beds containing *Uintacrinus* and *Marsupites* plates. As far as we can trace them, the measurements work out as follows:

Uintacrinus-band	28 ft. 9 in.
Marsupites-band	48 ft. 9 in.
Total *Marsupites*-zone .	77 ft. 6 in.

Now let us leave the cliffs and stand out as far as we can get on the shore, and trace upward the two marl-bands, and the two flint-bands, to the *Castrum* at the top of the cliff. We find that the marl-bands run up to the west side of the *Castrum*, and then pass out at the top of the cliff; but that the two flint-lines, 9 ft. apart, pass further eastward. To follow these we must go eastward also, and by walking out on the reefs, opposite the oblique fissure-cave, we trace the two flint-lines as they pass out at the

E. THE CUCKMERE TO SEAFORD HEAD.

On the western side of the Cuckmere are low cliffs of a dirty yellow colour, but west of Hope Gap they rapidly rise, and form a very fine section. From the Cuckmere, to an oblique fissure-cave under the *Castrum*, the bulk of the cliff is in the *M. cor-testudinarium*-zone, a distance of $1\frac{1}{4}$ miles in this one zone. The oblique fissure-cave is an important feature, as it marks the actual junction of the zones of *M. cor-testudinarium* and *M. cor-anguinum*. At Beachy Head (200 yards east of Belle Tout) we are able to take a tabular flint-bed as the division line, but it does not exist here, and we choose in its place a closed marl-seam, which rises from the shore on the eastern side of the fissure-cave. This seam is constant throughout the section and is very easily traced, as the chalk often falls away below it, leaving a sharply-cut overhanging ledge. The fissure itself extends half-way up the cliff, and is iron-stained at the top, where it is intersected by the strong *M. cor-anguinum*-tabular, here 60 ft. above the beach, and is equivalent to the strong tabular in the same position at Belle Tout. This *M. cor-testudinarium*-chalk is deceptive in appearance, as it does not weather out in hard rugged knobs as at Dover and elsewhere, and passing along it in a boat, it was impossible to assign it to this zone from general appearances. The lithological features differ greatly from those at Beachy Head, and both the *M. cor-testudinarium*-tabular, and the "spurious tabular and sponge bed," are wanting. This is a good example of lithological features failing one in a restricted area. At Further Point the beds begin to show evidence of a strong dip to the west, and, by the time that we reach Seaford Head, they are inclined at an angle of about 10 deg.

Passing a little further west of the oblique fissure-cave, we trace the dip of the strong *M. cor-anguinum*-tabular to the shore, below the west side of the *Castrum*. Still passing westward we reach the point where two strong nodular flint-lines sink to the shore. These are clearly the same two flint-lines, 9 ft. apart, which we saw intersecting the bases of the highest of the "Sisters"; so it is probable that we are nearing the junction with the *Marsupites*-chalk. The only thing to do is to fix our division line by collecting. We accordingly begin at the upper of these two flint-lines, 9 ft. apart, and work eastward. We find no trace whatever of *Uintacrinus*; so we retrace our steps and start from the same point and work westward.

At once we find *Uintacrinus*. This gives us our junction line, and so that others may be spared the labour which we had in finding it, we give a measurement from the stone groyne at the east end of Seaford Esplanade, to the upper of two strong flint-lines, 9 ft. apart. We took a straight line along the beach, and this gave us 760 ft., from one point to another. The thickness of

the *M. cor-anguinum*-zone from this point to the marl-seam at the oblique fissure-cave was 242 ft. The next thing to do is to find *Marsupites* itself. At this juncture, it may be well to say that we went over this very area in the section most carefully in 1898, and failed to find a single *Uintacrinus* or *Marsupites* plate. This was due to the fact that every fossil is smashed by the shingle as soon as it weathers out. This time we determined to miss nothing, so we removed every piece of calcite from the cliff face and cleaned it. By this means we got all the evidence which we required. For 28 ft. 9 in. above the upper of two strong flint-lines, 9 ft. apart, we got *Uintacrinus*; and for 48 ft. 9 in. above the *Uintacrinus*-chalk we collected *Marsupites*. Then came a space of about 20 ft. in which we got no *Marsupites* and no *Cardiaster pillula*, but in which the *Echinocorys vulgaris* var. *pyramidatus* began to blend with the var. *gibbus*, and where *Rhynchonella plicatilis* was common. Wherever we have met with a junction between the two zones of *Marsupites* and *Actinocamax quadratus* we have found the same hiatus between *Marsupites* plates and *Cardiaster pillula*, and the blending of the associated guide-fossils. *Cardiaster pillula* invariably extends to the extreme base of the *Actinocamax quadratus*-zone, and we always fix the lower limit of this zone by its presence. The actual junction of the zones of *Marsupites* and *A. quadratus* can here be fixed by an open marl-band, 31 ft. above another open marl-band, and 470 ft. in a straight line along the beach to the stone groyne before mentioned.

We can now fix with certainty the upper and lower limits of our *Marsupites*-zone, for we know that *Marsupites* plates are not found above the second marl-band, and that *Uintacrinus* is not found below the upper of the two strong flint-lines, 9 ft. apart. Further observations may increase the downward measurement of the *Uintacrinus*-band, but not its upper limit; for we got a close contact between beds containing *Uintacrinus* and *Marsupites* plates. As far as we can trace them, the measurements work out as follows:

Uintacrinus-band	28 ft. 9 in.
Marsupites-band	48 ft. 9 in.
Total *Marsupites*-zone .	77 ft. 6 in.

Now let us leave the cliffs and stand out as far as we can get on the shore, and trace upward the two marl-bands, and the two flint-bands, to the *Castrum* at the top of the cliff. We find that the marl-bands run up to the west side of the *Castrum*, and then pass out at the top of the cliff; but that the two flint-lines, 9 ft. apart, pass further eastward. To follow these we must go eastward also, and by walking out on the reefs, opposite the oblique fissure-cave, we trace the two flint-lines as they pass out at the

zone, when not damaged by the shingle, but the parts which are in good order for working are limited.

There is no *M. cor-testudinarium*-tabular, as at Beachy Head (Belle Tout), but much in the same position we find a thin closed marl-band, which approximately marks the junction between this zone and that of *M. cor-anguinum*. The reader is referred to p. 327, where the same zone at Beachy Head is discussed. This section in no way differs from the other, save that it does not look like *M. cor-testudinarium*-chalk, and that several lithological details which are present in one place are absent in the other. There is no need to recapitulate the zoological details, as they are the same in both sections. About 80 ft. of this chalk is exposed, and we have worked the lowest part of it thoroughly, and find no trace of *Holaster planus*-zone fauna. *Micraster* shows no evidence of nearing that zone.

At this point it will be convenient to put in condensed form the lithological guides to the various zones at Seaford Head and their measurements.

MEASUREMENTS AT SEAFORD HEAD.

Zone of *Micraster cor-testudinarium*.	From lowest part of *M. cor-testudinarium*-zone to the oblique fissure-cave, where the closed marl-band divides this zone from that of *M. cor-anguinum* . . . . (about)	80 ft.
Zone of *Micraster cor-anguinum*.	From marl-band at oblique fissure-cave to place where the strong *M. cor-anguinum*-tabular sinks to the shore under the *Castrum*	62 ft.
	From spot where strong *M. cor-anguinum*-tabular sinks to shore, to where the upper of two strong nodular flint-lines, 9 ft. apart, sinks to shore	180 ft.
Zone of *Marsupites*.	From upper of two strong flint-lines, 9 ft. apart, to point where the last *Uintacrinus* plate and the first *Marsupites* plate were found	28 ft. 9 in.
	From spot where the last *Marsupites* plate was found to the upper of the two marl-bands (470 ft. from stone groyne)	48 ft. 9 in.
Zone of *Actinocamax quadratus*.	From upper of two marl-bands to top of *A. quadratus*-chalk, at west end of Seaford Head . . . (about)	170 ft.
	At Seaford Head. Total . .	569 ft. 6 in.

F. NEWHAVEN TO BRIGHTON.

The whole section can be worked when the tide is falling, and the points where the tide has to be watched are at the east and west corners of Friar's Bay, and the west side of Portobello. The points at which we can leave the shore are at Telscombe Staircase

(east of Portobello), Portobello, Saltdean, Rottingdean, and Brighton. There is a ferry across the river at Newhaven, opposite the Harbour Home. No freshwater springs are seen on the shore.

Still passing westward we find some fine cliffs at Newhaven, in the zone of *Actinocamax quadratus*, and we trace these on to a point half-way between Rottingdean and Brighton, where the cliff is faced with brick and surmounted by a tall shaft. On the shore, in front of the brick facing, are two strong groynes. There is, probably, a pumping-station here. Some 450 yards west of this we get the junction of the zones of *A. quadratus* and *Marsupites testudinarius*, and from here to Brighton, a distance of over a mile, the base of the cliffs is in the latter zone. The distance from Newhaven to the pumping-station is 6½ miles, so that omitting the low cliffs between Seaford and Newhaven, and those at the west end of Seaford Head, which are also in the *A. quadratus*-zone, we have nearly seven miles of continuous cliff-section, all cut in the lower part of the zone of *A. quadratus*. It stands to reason that, with such a length of section in one zone, the beds must be practically horizontal, and such indeed is the case. This is the most extensive section in England in the *A. quadratus*-zone.

Cardiaster pillula, *Echinocorys vulgaris* var. *gibbus*, *Actinocamax merceyi* (never common), *Ammonites leptophyllus*, together with other characteristic fossils of a basal *A. quadratus*-zone fauna, occur uninterruptedly throughout. The Bryozoan bed occurs on both sides of Rottingdean Gap, but beds of these organisms, of a less prolific nature, are met with in other parts of the section.

This broad statement requires qualification, for there is one very interesting and important exception to it, which it will be necessary to demonstrate in detail, as the occurrence of the *Marsupites*-band near Newhaven has never been suspected before.

Starting from Newhaven Fort, we find that the cliffs are in the *Actinocamax quadratus*-zone, full of *Cardiaster pillula*, and the other guide-fossils of this zone; and this condition is maintained as far as Old Nore Point, where the beds begin to rise to the west, and a thin tabular rises from the shore. The rise in the beds is not maintained, as there is a series of faults, which brings the tabular to the shore again in the centre of the bay. The reefs from Newhaven Pier to opposite Old Nore Point are in the same zone. Passing round Old Nore Point, we see a large bay, a mile long, the western end of which is marked on the 6 inch map (sheet 77) as Friar's Bay. The reefs appear to lie at a lower level here, and this idea is strengthened if we go out upon them and look towards those at the western angle of Friar's Bay, for we seem to stand below the latter.

On these reefs, 550 yards west of Old Nore Point, we found *Echinocorys vulgaris* var. *pyramidatus*, *Echinoconus conicus*,

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Micraster cor-anguinum, *Rhynchonella plicatilis*, and the large *Porosphæra globularis* in abundance, and we trace this rich fauna nearly to the middle of the bay, where it dies out, and is replaced by a less pyramidal form of *Echinocorys*, mingled with some *sub-gibbus* forms, and a smaller proportion of *Micraster cor-anguinum*. We are now clearly in the transition area between the zones of *Marsupites* and *Actinocamax quadratus*. Passing further on, towards the west end of Friar's Bay, we come to an abundance of *Echinocorys vulgaris* var. *gibbus* and finally to *Cardiaster pillula*. So much for the reefs, which give the passage from the true *A. quadratus*-zone fauna to that of the *Marsupites*-band, from the *Marsupites*-band to the transition area, and from the latter to the true *A. quadratus*-zone fauna again.

It is worthy of mention that this discovery of the *Marsupites*-band was made, not by finding *Marsupites* itself, but by noting the size, shape, and thickness of the broken tests of *Echinocorys*, and the presence of the large *Porosphæra globularis*. In *Echinocorys vulgaris* var. *pyramidatus*, the sides and base form an acute angle, and the test is much thicker at the angle than in *Echinocorys vulgaris* var. *gibbus*. The eye being attracted by this, was at once impelled to a closer search, and *Marsupites* was found in abundance. The big dome-shaped form of *Echinocorys* was also fairly abundant, and this was a further guide, as its relative frequency is much greater in the *Marsupites*-zone, than in the zone of *A. quadratus*.

Standing on the reef, we notice that our flint tabular-band sinks to the shore at the middle of the bay, where, in 1899, there was a great fall of rock, rich in *Cardiaster pillula* and other *A. quadratus*-zone forms. It is clear that the cliff, in the western half of the bay, must be in the true *A. quadratus*-chalk ; and the only point to decide is the nature of the beds between Old Nore Point and the centre of the bay, where the flint tabular sinks to the shore. On examining it we found one *Marsupites* basal-plate, an abundance of the sub-pyramidal form of *Echinocorys*, *Rhynchonella plicatilis*, six *Actinocamax merceyi*, and seven *Micraster cor-anguinum*, but no *Cardiaster pillula*. We know that at Seaford Head, and beyond the Pumping Station, near Brighton, where we get a junction of the zones of *Marsupites* and *Actinocamax quadratus*, we find the same fossils; so that it is clear that, in this eastern part of the bay, we are in the transition area between the two zones—an area which we can couple to the *Marsupites*-band, because the sub-pyramidal *Echinocorys* belongs more to that bed than to the zone above, and that *Micraster cor-anguinum* is one of the rarest fossils in the *A. quadratus*-zone. It is evident, therefore, that we have here, for a distance of about half-a-mile, a little exposure of *Marsupites*-zone in the cliff. The value of correlating the reefs with the cliffs is very apparent all along this section, and we only regret that the state of the tide

and limited time, prevented us from examining the whole of the reefs from the west end of Friar's Bay to Rottingdean, as it is quite possible that we might get a trace of the *Marsupites*-band in other places at extreme low tide. Such parts of the reef as were examined only revealed evidence of the *A. quadratus*-zone.

Barrois puts all the section from Birling Gap to Brighton, with the exception of a base of *M. cor-anguinum*-zone at the Seven Sisters, and of *M. cor-anguinum* and *M. cor-testudinarium*-zones at Seaford Head, into the *Marsupites*-zone; and the reason for this course has been explained by the fact that he considered the "spurious tabular and sponge bed," at Birling Gap, to be analogous to the "Whitaker 3-inch" tabular and the "Barrois sponge bed," at the top of the *M. cor-anguinum*-zone in Thanet. The fact that he found *Actinocamax merceyi*, at the Seven Sisters, at Seaford Head, and between Newhaven and Brighton, gives confirmation to this view, for this fossil occurs in the *Marsupites*-zone. We know, however, that it is equally a factor in the basal *A. quadratus*-zone fauna. The occurrence of this fossil at the Seven Sisters is very curious, and can only be explained on the supposition that it was found on a fallen block from the top of the highest and most western "Sister," on the top of which we found *Uintacrinus* and two *Marsupites* plates. It must have come from the very thin cap of *Marsupites*-band there, or it may have been one of the very rare occurrences, low in the *Uintacrinus*-band, such as we find at Margate.

Dr. Barrois told the writer that the whole of this wonderful survey of the English Chalk was done at express speed, and that very little time could be spent in collecting. Had he been able to spend the same amount of time, which we have done, in collecting, it is reasonable to assume that his arrangement of the beds, from Birling Gap to Brighton, would have been different. It must be remembered also that he had not the advantage of using *Uintacrinus* as a zonal-guide. In any case, this is a small defect in a work of marvellous insight and induction—a work which has been the standard authority for over twenty years, and one which will stand the test of time and future investigation.

The danger of trusting entirely to a lithological feature is well borne out here, and it shows that all zonal boundaries must be fixed on zoological evidence, and on that alone.

Zone of Actinocamax quadratus.

FROM NEWHAVEN TO A POINT 550 YARDS WEST OF THE PUMPING STATION, BETWEEN ROTTINGDEAN AND BRIGHTON; INCLUDING THE 170 FT. OF THIS ZONE AT THE WEST END OF SEAFORD HEAD AND THE LOW CLIFFS BETWEEN SEAFORD AND NEWHAVEN.

This is a variable zone for fossils, being exceedingly rich at some levels, and barren in others. It is always prolific in the

lowest part. This variability is well borne out in the Sussex Coast.

The zone is characterised by a rather soft white chalk, greyish in places, from admixture with marl, but often of a yellow colour, from diffused staining with iron. Marl-bands, which often weather out as open seams, are common, and so are tabular and nodular flint-bands; but the latter never occur with the regularity of those in the zone of *Micraster cor-anguinum*. We know of no chalk so full of tabular flint as this, and oblique fissures in the chalk are frequently infilled with thin layers of flint. Slickensiding is sometimes present. Fossils from this chalk are by no means easy to clean, on account of the adherent nature of the marl, and are best worked in a moist state. We know of no bed where the spines of *Micraster* and of *Echinocorys* are so frequently adherent to the test, and this is doubtless due to the intimate admixture of the marl with the chalk. The flints are commonly of a pink colour outside, sometimes with a thick, and at others with a thin, cortex; but the colouration varies much even in a limited area.

As before stated, the beds are practically horizontal all along this extended section, and no lithogical features need be mentioned until we pass the Electric Railway Station at Ovingdean, where the beds clearly begin to rise gently as we pass to the west. From this point we now take up the closer examination of the section, as we are nearing the junction with the *Marsupites*-chalk, and all the beds east of this have been proved, by collecting, to be in the zone of *Actinocamax quadratus*, and rich in the characteristic fossils of that zone.

Opposite the fourth electric standard-pole, west of Ovingdean Station, a thin tabular rises from the shore and we trace this to the level of the top of the two stone groynes at the Pumping Station. Below this tabular, *Cardiaster pillula* dies out and *Echinocorys vulgaris* begins to pass insensibly from the var. *gibbus* to the var. *pyramidatus*. It is clear that we are almost in the *Marsupites*-band. There are no lithological features to guide us, and we must trust here, as elsewhere, to zoological evidence.

Passing westward over the two stone groynes, we find an open marl-band rising from the shore, between the second and third electric standard-poles, on the west side of the more western groyne. This marl-band forms the top of a wrought cave, opposite the fifth pole, west of the groyne. Collecting between this marl-band and the thin tabular, which is level with the top of the groynes, we obtained fourteen examples of *Echinocorys*, twelve of which approached the shape of the var. *pyramidatus*, and a number of *Rhynchonella plicatilis*, but no trace of *Cardiaster pillula*. Still going west we found the first *Marsupites* plate, at a spot opposite the ninth standard-pole. This gives us the point at which the name-fossil comes in at the cliff, but we can safely take

the top of the zone up as high as the mark-band [illegible] and our measurements will be taken from that level.

Leaving the cliff, and examining the reefs, which, from their position, are at a lower level in the zone, we collected *Marsupites* plates as far east as the third standard-pole, west of the groyne, and east of this point we failed to trace them. The difference which the slightly lower level of the reef makes is notable, for we find that, taking the distance between the poles as 50 paces, we discover *Marsupites* 300 paces further east on the shore than in the cliff.

Returning to the cliff, it is clear that, directly we pass the ninth standard-pole, we are well in the *Marsupites*-band; and the further west we go the more obvious does it become, as the plates are more abundant. Towards Brighton they become fewer, for we are getting lower in the *Marsupites*-band. We looked for *Uintacrinus* on the reefs facing the elephant-bed, but failed to find it. *Marsupites*-plates were found there, so it is plain that we have not quite reached the bottom of the *Marsupites*-band at this spot, though this particular bed is 58 ft. thick.

There are but few pits near the coast. Two small exposures on the south side of the road, between Portobello and Newhaven; a small roadside excavation, half-a-mile north-east of Rottingdean, on the road to Newlands Farm; a drain-trench between Brighton and Roedean School; and a large pit north-west of St. Mark's Church at Brighton. All these are in the zone of *Actinocamax quadratus*. The drain-trench runs from opposite a new house called "Downside," which is a little to the east of the Golf-house; and in the chalk from this trench we found *Ammonites leptophyllus*. This was at a level of about 130 ft. from the shore, and a second *Ammonites leptophyllus* was found south of the Golf-house, on about the 200 ft. contour-line.

Typical Fossils of the Zone of Actinocamax quadratus as exposed in Sussex.

As this section only gives us a portion of the zone, it is impossible to give the complete zoological divisions.

Cardiaster pillula *Echinocorys vulgaris* var. *gibbus*	throughout	about 170 ft. exposed.
Actinocamax merceyi *Ammonites leptophyllus*	chiefly in lower part	

Other characteristic fossils are *Porosphaera*, *Trochosmilia* (*Cœlosmilia*) *laxa*, *Bourgueticrinus* (a special form), *Serpula turbinella*, *Eschara danae*, *Vincularia santonensis*, and *Crania egnabergensis* var. *striata*. There is a special undescribed form of *Cribrilina*, which will shortly be figured. This is abundant in

every section of this zone which we have worked, and is highly characteristic.

The almost complete absence of *Micraster cor-anguinum* is as good a distinction, between this zone and that of *Marsupites*, as the most typical guide-fossils would be.

Cardiaster pillula occurs in bands, from the base to the top of the chalk (170 ft.), as exposed here. This is essentially a gregarious urchin, for when we find one example we generally expect to see more. It is especially large and common at the bottom of the zone, attaining the dimensions of an *Echinoconus*, but we have found very large examples as high up as 120 ft. At a small road-side exposure, on the Newlands Road from Rottingdean, we obtained sixty-four in half-an-hour. This is essentially the dominant fossil in this zone, and for so abundant a form its range is fairly restricted to the upper and lower limits of the *Actinocamax quadratus*-zone. In Sussex we have never found it in the *Marsupites*-band; but at Margate, the writer has a solitary young example, which was found below the " Bedwell-line," in the upper part of the *Uintacrinus*-band. Mr. Griffith tells me that it is occasionally found in the *Belemnitella mucronata*-zone in Hampshire. In our experience, this urchin becomes rarer in the upper part of the zone, but we can always count upon sporadic occurrences as far as the upper limit of the zone.

Echinocorys vulgaris var. *gibbus* is a very common fossil, and an admirable zonal-guide. It is most abundant in the lower part of the zone, and has a tendency to run in bands. It passes insensibly from a sub-pyramidal form, at the base of the zone, to a more truly gibbous form. As in all the higher zones, we find a large dome-shaped form, rather more pointed in shape than in the *Marsupites*-zone. It will be interesting to contrast the var. *gibbus* in this zone with that in the zones of *Holaster planus* and *Micraster cor-testudinarium*. Bryozoa are very abundant in all three zones, and the adnate forms are so characteristic as to afford a ready means of distinction between the zone of *Actinocamax quadratus* and the two lower zones. Apart from this, however, there are certain features of the test, which are sufficiently constant to be worthy of mention. On the whole, the size of the *Echinocorys vulgaris* var. *gibbus* in the *A. quadratus*-zone is decidedly smaller than that in the two lower zones; its base is notably flatter; the sides of the test are straighter, and less rounded; and the anus is far more sub-marginal in position, instead of being marginal, as is the rule in the two lower zones. Naturally, there would be no difficulty in separating the two forms in the field, for both the associated fossils and the lithology are so divergent that no confusion could arise. Inexperienced collectors, however, often send us urchins for determination, so that it is useful to have data upon which we can rely in the study, and it is for this reason that these observations are brought forward. There is no large dome-

shaped form in the two lower zones. At the base of the zone we find a very characteristic dwarfed pyramidal form, often no more than 33 mm. in height, and 22 mm. in length. The writer has found this in every basal section of this zone which he has worked; Dr. Blackmore records the same fact at Salisbury, and was the first to call his attention to it. It is a perfectly characteristic form, unlike anything else, and quite diagnostic of the base of the zone. This small variety is an edition in miniature of *Echinocorys vulgaris* var. *pyramidatus*, even to the heaping-up of the apical disc at the angle of the ambulacral junction.

Actinocamax merceyi is only found in the lower part of this zone, and we have no record of its occurrence at a greater height than 150 ft. from the base. Our specimen was obtained from a fallen block; but, from the position of the block, we can fix its situation accurately. Another specimen was found, *in situ*, 120 ft. from the base. Both these were at Seaford Head. No trace of *Belemnitella lanceolata* could be found at Seaford Head, where we get the greatest thickness of the zone, though careful search was made for it. The example of *Actinocamax merceyi*, recorded by Barrois from Seaford Head, was found at the 120 ft. level, for we have a letter from him in which he indicates the exact spot at which he found it. Our example was broken, but Dr. Barrois' determination makes it clear that it was probably an example of *Actinocamax merceyi* and not of *Actinocamax quadratus*. Our example recorded from the 150 ft. level was also broken, and had no alveolar cavity. We submitted it to Mr. Crick, who said that it showed considerable resemblance to *Actinocamax quadratus*, and possibly was that species. It was, however, too imperfect for accurate determination. From previous experience we should have expected that Belemnites found at this level would have been of the form known as *Actinocamax quadratus*, and that those found at the base of the zone would be the typical *Actinocamax merceyi*. Mr. Crick has seen all our Belemnites from this coast, and he referred them all to *Actinocamax merceyi*, with the exception of the single dubious example at the 150 ft. level. There is no difference between *Actinocamax merceyi* as found in the *Marsupites*-band and that found in the *A. quadratus*-zone; and all that we can affirm as to its zonal value is that it is indicative of either the lower part of the *A. quadratus*-zone, or of the *Marsupites*-band, as there is nothing to point to its occurrence in the *Uintacrinus*-band in Sussex. The associated fossils will at once give a clue, as there is never any difficulty in separating the two zones in the field. We did not find *Actinocamax merceyi* at all in the *Marsupites*-zone at Seaford Head, but there the beds are dipping at 10 deg., and the section is a very short one in consequence. We have found it at intervals all along the base of this zone, from Newhaven to the Pumping Station between Rottingdean and Brighton.

Ammonites leptophyllus is found in considerable numbers in the base of this zone, from Newhaven to the Pumping Station. Whether it is the same species as that which occurs in such abundance in the Brighton *Marsupites*-band, must be left to a specialist in cephalopoda to decide. It reaches an immense size in Sussex, frequently 4 ft. across, and one gigantic example, which we measured, was 66 inches in diameter. This establishes a record for Chalk Ammonites. We found none, *in situ*, at Seaford Head in this zone. The highest range which we have recorded is at the drain-trench south of "Downside." We have something like 40 ft. of the *Marsupites*-band in the cliff at this point, so the Ammonites must have been respectively about 90 and 150 ft. above the base of the *Actinocamax quadratus*-zone. This is a very high occurrence, and we have been unable to detect any others so high up in the cliff.

Porosphæra is also a good guide-fossil. *Porosphæra globularis* is often large, but not so large as in the *Marsupites*-zone. *Porosphæra woodwardi* and *P. pileolus* are of large size and great numerical strength. We regard an abundance of *Porosphæra woodwardi* of large size as especially suggestive of this zone.

Parasmilia (*Cœlosmilia*) *laxa* is highly characteristic of this zone, and as it is generally abundant, is a good guide-fossil. We have found it in every section in this zone. The corals are generally small. Other common forms are *Parasmilia fittoni* and *P. cylindrica*.

Bourgueticrinus has a characteristic head in this zone, is always abundant, and an excellent zonal-guide. It occurs in all sections in this zone which we have worked. This form Dr. Blackmore first introduced to the writer's notice, before he had much experience in this zone, and he gladly records the fact of its universal occurrence and usefulness. There is also a dumb-bell-shaped columnar which is characteristic, but not so common. This dumb-bell-shaped columnar is merely an exaggeration of the dominant columnar of the zone, which is longer and thinner, with expanded ends and a contracted centre (Pl. VIII, Fig. 11). *Bourgueticrinus æqualis* is found, and sometimes reaches a large size. It is not peculiar to this zone, but is found in the zones of *Marsupites testudinarius* and *Micraster cor-anguinum*. This also occurs in all sections.

Serpula ilium is of large size (6 to 20 mm. in its largest diameter), and is very common and characteristic in Sussex *Serpula turbinella* is not so common as the last, but is a useful guide, though not confined to this zone.

The Bryozoa are very abundant and characteristic, and in our hands have proved one of the most useful of zonal guides; but as several of the most characteristic forms are not figured, it is impossible to refer to them. They will shortly be figured and described by Mr. R. M. Brydone and the writer.

Vincularia santonensis is quite a characteristic form, and *Eschara danae* is even more so. The latter can be determined without the aid of a lens, so marked are its characters. *Vincularia disparilis* is found in great profusion in this zone, but as it is also rather common in the two zones immediately below, it can hardly be regarded as a reliable zonal guide. There is also an undescribed form of *Cribrilina*, which is equally abundant and characteristic. All these forms are prevalent in every section of this zone which we have worked.

In Sussex, *Rhynchonella plicatilis* occurs in great abundance in the *Marsupites*-band, and, to a less extent, in the extreme base of the *A. quadratus*-zone, being large and flat in both instances. When we pass well into the *A. quadratus*-zone, however, it becomes smaller and more inflated, and the var. *octoplicata* is the dominant form. *Rhynchonella limbata* is found in this zone, but is not so common as in the *Belemnitella mucronata*-zone. *Crania egnabergensis* var. *striata* is common in this zone. It would appear that in this zone, and in that of *Marsupites*, the costæ tend to become fewer, leading up, as it were, to the var. *costata*, which is only found in the zone of *B. mucronata*.

There is a band of *Ostrea wegmaniana* in the passage-bed between the zones of *Marsupites* and *A. quadratus* in Sussex. *Ostrea lateralis*, though by no means confined to this zone, reaches its highest development here. It extends, with decreasing frequency, as low down as the zone of *T. gracilis*. *Ostrea lateralis* var. *striata* is, in our experience, only found in the zone of *A. quadratus*.

Sponges are very abundant and well preserved, and are by no means devoid of interest as zonal-guides.

Whether *Actinocamax quadratus* is a good name-fossil for this zone is open to question. Were not *Belemnitella mucronata* such an excellent name-fossil for the zone above, thus giving a continuity between the two species, it would be much better to do away with the present name for the lower zone, as far as England is concerned.

$\left.\begin{array}{l}\textit{Actinocamax quadratus} \text{ in upper part} \\ \textit{Actinocamax merceyi} \text{ in lower part .}\end{array}\right\}$ zone of *Cardiaster pillula.*

The above scheme would much better meet most English sections with which we are acquainted, as *Actinocamax merceyi* is so frequently a rare fossil. However, it would seem to be a pity to break into the continuity of the Belemnites, and we have, therefore, kept to the old arrangement. As long as we recognise the exact mutual relationship of the various well-defined species of Belemnites, it matters but little by what names we call the zones which mark their individual horizon. In other districts *Belemnitella lanceolata* is found in the lower part of the zone, but, like

Actinocamax merceyi, it is not of universal occurrence. *Belemnitella lanceolata* is found in the lower two-thirds of this zone at Salisbury, according to Dr. Blackmore, and Mr. C. Griffith tells me that it is a rare fossil in Hampshire, where, in contradistinction to Salisbury, it occurs at the very top of the zone, and is even occasionally associated with examples of *Belemnitella mucronata*. The most careful search failed to reveal a single example in Sussex.

Zone of Marsupites testudinarius.

FROM 550 YARDS WEST OF THE PUMPING STATION TO BRIGHTON, AND INCLUDING THE SHORT EXPOSURES AT SEVEN SISTERS AND SEAFORD HEAD.

The exact position of the top of this zone, both in the cliff, and on the reefs, near Brighton, has already been indicated on p. 340, and need not be recapitulated. The chalk is soft and marly, with nodular and tabular flint-bands and marl-seams. No one could distinguish this chalk from that of the zone above, and the only difference is that the flints have a thin white cortex instead of a pink one. Even this distinction fails one at certain places in the section. Anything more unlike the *Marsupites*-chalk of Margate or Salisbury it would be impossible to imagine. There is no lithological break to divide this zone from that of *Actinocamax quadratus*.

The only way to get an idea of the thickness of the whole zone is to correlate the sections at Brighton, Seaford Head, and the Seven Sisters. The thickness of the exposure of the *Marsupites*-band at Brighton is 58 ft. The thickness of the same band at Seaford Head is given as 49 ft., and, considering the difficulty of obtaining zoological evidence at this place (and measurements are only made on these grounds) on account of the battered state of the cliff, the measurement comes out pretty well. How much more of the *Marsupites*-band there is at Brighton it is impossible to say, as no *Uintacrinus* could be found either in the cliff or on the reefs. That *Uintacrinus* does occur somewhere in the Brighton area may be inferred from specimens of that fossil in the Brighton Museum, which are described as *Marsupites*, and stated to have come from Brighton. It is probable that the band will be found on the foreshore at Brighton. Barrois says that Marsupites occur at Shoreham, and this fact, coupled with the known dip of the *Marsupites*-band at East Brighton seems to indicate a gentle undulation such as we have described in Friar's Bay, and one which would expose a few feet of the lower band (*Uintacrinus*-band) in the centre of the arch, *e.g.*, Brighton, somewhere just west of the Aquarium. The thickness of the *Uintacrinus*-band is given as 28 ft. 9 in. Further, and more fortunate, search may increase the downward measurement somewhat. So little is at present known of *Uintacrinus* that it is

impossible to expect much evidence of its occurrence in the Sussex sections, save those which we have recorded. Anyone working in the Brighton area would do good service by examining the reefs at low water.*

The Broad Zoological Divisions of the Zone of Marsupites testudinarius.

a.	*Marsupites testudinarius* *Actinocamax merceyi* *Ammonites leptophyllus* *Echinoconus conicus* *Echinocorys vulgaris* var. *pyramidatus* *Terebratulina rowei* *Bourgueticrinus*, a special form !	*Marsupites*-band maximum thickness exposed, 58 ft.
b.	*Uintacrinus* *Echinocorys vulgaris* var. *pyramidatus* *Bourgueticrinus*, the same special form *Terebratulina rowei*	*Uintacrinus*-band maximum measurement yet obtained, 28 ft. 9 in.

A comparison of this table with that given for the Thanet coast will at once afford a striking contrast (p. 296). It will be seen that *Ammonites leptophyllus*, instead of being associated with the *Uintacrinus*-band, is referred almost entirely to the *Marsupites*-band, and that it, or a form much resembling it, extends upwards into the zone of *Actinocamax quadratus*. We have but one record of the occurrence of the Ammonite *in situ* in the *Uintacrinus*-band. Under the Seven Sisters we found several fragments resembling an Ammonite in very bad preservation. One of these we sent up to Mr. Crick, who unhesitatingly referred it to that genus. Two of these blocks we can localise with certainty, for they occurred in a recent fall which was clearly in *Uintacrinus*-chalk, with the merest trace of *Micraster cor-anguinum*-chalk below it. The turf-cap was still attached to the top of the fall, and under the turf were abundant *Uintacrinus* plates, but no *Marsupites* plates. The other blocks were on the shore, and we could not tell their origin. No trace of an Ammonite have we found *in situ* throughout the whole long stretch of *M. cor-anguinum*-chalk. We carefully record these facts, giving them for what they are worth, in the hope that other observers may throw further light upon them. Dr. Barrois tells the writer that *Ammonites leptophyllus* is not found in France. We have found no trace of *Aptychus* in this zone, or in that of *Actinocamax quadratus*, in Sussex.

For years past we have heard of *Marsupites* being found at Rottingdean, and its occurrence there has always been a puzzle. Repeated search in the cliff has failed to reveal to us a single

* Since writing the above, Mr. W. McPherson has found a plate of *Uintacrinus* on the reef facing the Elephant-bed at Brighton. It is clear, therefore, that we have there the junction of the *Marsupites*- and *Uintacrinus*-bands.

plate between Rottingdean and the ninth electric standard-pole, west of the groyne at the Pumping Station.

Examination of the reefs, between Rottingdean and the Pumping Station, has led to a similar negative result. The landlord of the "White Horse," Rottingdean, tells us that he has found whole tests in the rolled fallen blocks under "Greenway," which is between Rottingdean and Ovingdean Electric Station. We know that the blocks from the Elephant-bed, at Brighton, travel as far as this, and we can only account for the occurrence of *Marsupites* on this assumption. He has never found them in falls from the cliff, as was reported. We know that there is a strong westerly drift along this coast. The "Peruvian," laden with ivory-nuts, was wrecked at Seaford on February 8th, 1899, and in November, 1899, these nuts were found on the shore as far as Eastbourne.

Actinocamax merceyi does not extend so low in the *Marsupites*-band as in Thanet. Its maximum of occurrence appears to be in the upper 20 ft. of the *Marsupites*-band, and the extreme base of the *A. quadratus*-zone. We had not time to thoroughly work the reefs close to Brighton, but a rapid examination of them gave a negative result. We found no *Actinocamax merceyi* in the *Marsupites*-zone at Seaford Head, or at the Seven Sisters. The two places where we found most specimens, were immediately west of the Pumping Station and in the eastern half of Friar's Bay, where the passage-bed between the zones of *Marsupites* and *A. quadratus* occurs. *Actinocamax merceyi* is fairly common on the fallen blocks near Brighton, but we have not succeeded in finding one *in situ* lower than 20 ft. down in the *Marsupites*-zone.

We have found no trace of *Actinocamax verus* throughout the whole section, though we have especially searched for it. Mr. W. McPherson has, however, given me a small broken Belemnite, which he found on a rolled block close to Brighton. Mr. Crick has identified this as *Actinocamax verus*. Not only is it absent in the *Uintacrinus*-band, but it has not been found in the zone of *M. cor-anguinum* in this locality, though it occurs in Hants. and in Norfolk, according to the testimony of Mr. C. Griffith and Mr. W. Hill. It is a rare fossil in both these counties. Since writing the above, Mr. Griffith has kindly shown me several of these Belemnites, and they appear not to be examples of *Actinocamax verus*, but of a form closely resembling it. In a recent letter, Mr. Hill states that he only found a few fragments of Belemnites, resembling *Actinocamax verus* in size and shape, but that they were too imperfect to warrant an exact determination. Mr. G. E. Dibley states that *Actinocamax verus* is found in the zone of *M. cor-anguinum* in the Gravesend district. We have seen these specimens and they undoubtedly belong to this species. Dr. Barrois tells the writer that, in France, *Actinocamax verus* is found in the upper part of the zone of *M. cor-anguinum*, and that it

ranges up into the *Marsupites*-zone. He does not look upon it as essentially a *Marsupites*-zone form. *Marsupites testudinarius* is a rare fossil, and there are very few sections of this zone in France. He further adds that it is very difficult in France to separate the zones of *Micraster cor-anguinum* and of *Marsupites*.

Echinoconus conicus is not found in a band at the base of the zone, as in Thanet, but on the contrary is rare here, and is only found with any frequency in the *Marsupites*-band, and is far more common in the top of that band than it is in Thanet. It is nearly always of the rounded type—the forma *conica*—and we found no examples of the large forma *pyramidalis*, and even well-marked smaller specimens of the last-named type, which is the commonest form in Thanet, are comparatively rare. No *Echinoconus* was found in the zone of *Actinocamax quadratus*.

Echinocorys vulgaris var. *pyramidatus* is as certain a zonal-guide here as in Thanet, and its maximum degree of acumination is reached where *Marsupites* plates are thickest. It is here that we get the remarkable heaping-up of the apical disc, together with the bossing at the summit, where the ambulacral areas converge, so notable in extreme examples. There is no band of this urchin here, but it occurs uniformly and frequently throughout.

Terebratulina rowei is a perfectly reliable zonal guide in every section which we have worked. We found twelve examples on the little bare patches on the top of Seaford Head and the Seven Sisters; so it seems to be common in both the *Marsupites*-band and the *Uintacrinus*-band. In two hours we found twenty-three examples in the *Marsupites*-band at Brighton and during this time we only saw two specimens of *Terebratulina striata*.

The relative positions of *Marsupites*, *Uintacrinus*, *Ammonites*, *Actinocamax merceyi*, *A. verus*, and *Echinoconus*, at Salisbury, correspond closely with those at Margate, according to Dr. Blackmore. On the other hand Mr. Griffith states that *Echinoconus* is not a characteristic fossil of this zone in Hampshire. We see, therefore, that the zone is rather fickle in its faunal relations, and that the only constant factors are *Marsupites* occurring in the upper part and *Uintacrinus* in the lower. There is no "Barrois sponge-bed" at Salisbury, nor in Sussex. In a flinty chalk like that of Sussex it would be idle to look for a "Bedwell-line." The Salisbury *Marsupites*-chalk is, like that of Margate, soft, flintless, and devoid of marl.

What has been written concerning *Bourgueticrinus*, *Porosphæra*, *Kingena lima*, and *Serpula turbinella*, in the Thanet section, applies equally well here. On the other hand *Rhynchonella plicatilis*, so rare at Margate, is found in great profusion throughout the *Marsupites*-band. It is especially common at the top of this band and at the base of the *Actinocamax quadratus*-zone.

There is a great development of *Doryderma ramosum* in this zone at Brighton, and the flints are full of this sponge.

Measurements of the Zones in the Sussex Coast.

The approximate measurements in the White Chalk of the coast of Sussex are as follows:

Zone of *Actinocamax quadratus* (as exposed)	170 ft.
„ *Marsupites testudinarius* . . .	77 ft. 6 in.
„ *Micraster cor-anguinum* . . .	242 ft.
„ *Micraster cor-testudinarium* . .	109 ft. 6 in.
„ *Holaster planus*	48 ft.
„ *Terebratulina gracilis* . . .	170 ft.
„ *Rhynchonella cuvieri* . . .	100 ft.
	917 ft.

Sheets of 6-inch Maps employed (Ordnance Survey).

It is impossible to understand coast-sections aright, or to work them conveniently, without the 6-inch maps of the Ordnance Survey. If each worker will put in his zonal junctions on the map, as ascertained by purely zoological evidence, he will do much, not only to check our results, but to supply our deficiencies. To this end we append the numbers of the sheets necessary.

Birchington to Pegwell . .	Sheets 25, 26, 38, 37.
Kingsdown to Folkestone . .	Sheets 68, 75.
Eastbourne to Brighton . .	Sheets 80, 83, 82, 79, 78, 77, 66.

Conclusion.

It might have been better to have described the sections in each county from below upwards, instead of reviewing the beds, as we pick them up, passing from east to west along the coast; but there has been no time to recast the paper.

Long though the paper undoubtedly is, the writer is conscious of many omissions, not a few of which could readily have been supplied, had there been more time at his disposal. The lists in no sense represent the material collected, as there are several thousand specimens which it has been impossible to clean and accurately determine. Zoology has been so long the patient handmaiden to lithology, that no excuse need be offered for showing cause whereby the two subjects may be placed on an equal footing.

In working a vast coast-section, like the one under consideration, with its extensive zonal range, one of the most interesting problems which arises is the zonal variation manifested in the bulk of the common fossils. We have traced this variation in some of the more important groups, but much more might be written, did space permit, concerning the Brachiopoda and

Lamellibranchia. Indeed, there is hardly a group in which this zonal variation may not be traced with profit, and it is hoped that this may be done in a subsequent communication. The main difficulty is one of illustration, as however well the individual collector may know the variations they can only be made useful to other workers by means of plates.

The Chalk Lamellibranchia are in such a chaotic state that no excuse need be offered for determinations which are not strictly accurate. The same remark applies to the Bryozoa, which are so useful as zonal guides. Mr. Henry Woods is dealing with the former, and Dr. J. W. Gregory is describing the latter ("Cat. Creta. Bryozoa," Brit. Mus., 1899), so that both these interesting groups will be placed on a secure footing.

It will probably be noticed with surprise that no direct allusion has been made in this paper to vertebrate remains. The omission is intentional, for even shark's teeth are, comparatively speaking, so rare, that no reliance can be placed upon them as zonal guides in cliff-sections. Quarry-workers, like Mr. G. E. Dibley, may feel inclined to traverse this contention, for in certain quarries in Kent the crushing-teeth of sharks are found in great abundance. Still, these occurrences are purely local, and, as such, have but little value in tracing a zonal range.

On reading the manuscript again the writer feels that, while he has laid all possible stress on the extreme importance of studying these rocks from a purely zoological standpoint, he may possibly have failed to give sufficient value to the lithological features. This view has been strengthened by some remarks made by the President, Mr. Teall, when the paper was read. While no testimony, however powerful, can exaggerate the wonderful way in which the zonal theory is established by careful collecting over a wide area, it is equally true that, in many instances, the lithological features are fully as constant and rigid in their persistence.

The ideal coincidence of a constant zonal fauna and a constant lithological facies is well brought out, in the south of England, in the case of the zones of *Rhynchonella cuvieri*, *Holaster planus*, *Micraster cor-testudinarium*, *M. cor-anguinum*, and *Belemnitella mucronata*. Local variation, of course, plays its part even in these zones; but the fact remains that we can generally recognise the zones from the appearance of the chalk alone, and that the fossils act as confirmatory evidence. Still, in the light of accumulated zonal experience, nobody would venture to zone these beds, save on the evidence of their fauna, and zonal boundaries can only be established by patient collecting.

It will be noticed that no attempt has been made to make the thickness of the several zones correspond in the different districts herein discussed; and that, however tempting it may be to adopt lithological features as division-lines, they have been discarded, unless the zoological evidence clearly corresponds with them.

The zoological evidence here adduced has been obtained in the south of England coast-sections alone, and the writer disclaims any intention of making this evidence govern the distribution of fossils in other localities. He merely brings forward data obtained by personal collecting over a wide area; and as other sections are worked, further data will be secured, and correlated with them. The present inquiry must be regarded merely as an instalment up to date, as the zonal survey only embraces the coast-line of two counties. But, as far as they go, the writer believes that the conclusions are substantially accurate; and certainly no pains have been spared to avoid hasty generalisation, for the whole of his holidays, during the last ten years, have been devoted to rigid zonal-collecting, and the study of zonal variations.

No mention has been made of the terms Upper and Middle Chalk, or of their continental equivalents, as, save for mapping purposes, they can have but little value; for to any worker, who knows his fossils, the existing zonal divisions are all-sufficient. For convenient reference a table has been compiled by Mr. Sherborn, and will be found on p. 293. Further, no two observers seem to agree upon the exact point at which the base-line of the so-called Upper Chalk shall be placed. The fauna of the Chalk Rock seems to be the cause of all this uncertainty, on account of its "Cenomanian affinity." If this somewhat inconstant bed, with its peculiar fauna, be looked upon as an interpolation, in no way affecting the integrity of the fauna of the *Holaster planus*-zone associated with it, much of the difficulty is removed. As *Echinocorys* and *Micraster*, the two most abundant and characteristic fossils of the higher beds, only appear in earnest at the base of the *Holaster planus*-zone, it would be reasonable to place the base of the Upper Chalk there. Another phase of the difficulty has arisen in the desire to find a hard rocky bed wherewith to base the Upper Chalk, as a parallel to the rocky base of the *Rhynchonella cuvieri*-zone. It has been shown that the Chalk Rock is not always present, in a lithological sense, and, therefore, a lithological boundary of such inconstant occurrence can hardly seriously engage our attention. Though the Chalk Rock may be determined by microscopical examination, even when it is not strongly developed to the naked eye, such evidence, though of scientific interest, cannot avail us much, as it is useless in the field.

To many fellow-workers the writer would accord his grateful thanks, and above all to Mr. C. Davies Sherborn, who has shared his field-work during the past four years, and to whom he is indebted for the excellent coast-section, without which the text would have but little value. Much valuable information and kindly assistance has been given by Dr. Barrois, M. Jules Lambert, Mr. Jukes-Browne, Dr. G. J. Hinde, Dr. A. Smith Woodward,

Mr. H. Woods, Dr. Blackmore, Mr. Griffith, Mr. R. M. Brydone, General Cockburn, Mr. E. Westlake, Mr. G. E. Dibley, and Mr. W. Gamble, and the writer cordially acknowledges help so willingly given.

To Dr. J. W. Gregory and Dr. F. L. Kitchin, who have described the two new species in the Appendices to this paper, and to Mr. F. A. Bather and Mr. G. C. Crick, who are working on material contributed by the writer, sincere thanks are due. Mr. Bather has also kindly supervised the drawing of *Uintacrinus* plates for the paper, and is responsible for the description of the figure on p. 298. It was felt that a good figure of this essential guide-fossil would be of real assistance to zonal workers, and that the paper would be incomplete without it.

APPENDIX A.

By Prof. J. W. GREGORY, D.Sc., F.G.S., F.Z.S.

ZEUGLOPLEURUS ROWEI, n.sp.

Diagnosis.—Test very small, turban shaped; flat-based, subconical above; tall in proportion to its size; circular or subpentagonal in outline.

Apical system prominent; thickened on the margin beside the periproct. Madreporite covering three-quarters of its genital. Posterior radial marked by a median depression. Periproct pentagonal.

Ambulacral plates numerous; epipodia highly oblique. The plates begin as simple primaries, but soon become compound plates of two fused primaries.

Interambulacral plates about 8 to 9 in each series.

Epistroma of very abundant granules, which are crowded and subequal in size. A very small primary tubercle occurs in the ambital interambulacral plates, and lines of granules radiate from it. No ridges. Scrobicular area well marked and depressed.

Peristome large; subcircular.

Dimensions	B.M.75,556 *b*	Dr. Rowe's	B.M.75,556 *a*
Height of Test	3 mm.	4 mm.	5·5 mm.
Diameter of Test	4·25 mm.	5·5 mm.	8 mm.
Diameter of Peristome	(unseen)	1·75 mm.	(unseen)

Distribution.—Upper Chalk, Charlton; Marsupites-zone, Margate; *Micraster cor-anguinum*-zone, between St. Margaret's Bay and Kingsdown.

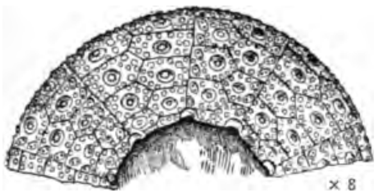
Affinities.—This small urchin is most nearly allied to *Zeuglopleurus costulatus*, Greg.,* from which it differs by being

* J. W. Gregory, On *Zeuglopleurus*, a new genus of the family Temnopleuridæ from the Upper Cretaceous. *Ann. Mag. Nat. Hist.*, ser. 6, vol. iii, pp. 490-500; 1889. See p. 495.

taller in proportion to its diameter, having a larger peristome, a pentagonal periproct, and no ridges connecting the primary interambulacral tubercles. The epistroma is altogether more primitive.

The characters and the small size suggest that the echinid may be a young form ; but as Dr. Rowe has found several specimens which are all small, it is probably entitled to specific distinction.

The British Museum Collection includes two specimens from Charlton (No. 75,556, *a* and *b*), which in 1889 I accepted as young forms of *Z. costulatus*, and on whose evidence alone I quoted that species as occurring in "Mid Chalk of Charlton" (*op. cit.*, p. 496); the peristomes in these specimens are covered by chalk matrix. It follows that *Z. costulatus* is now known only from one specimen, namely, that found in Chalk Marl at Glynde, Sussex (Brit. Mus., E 4,365).



× 8

FIG. 2.

FIG. 3. × 15

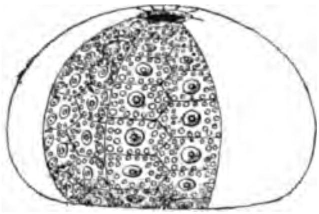


FIG. 1. × 7

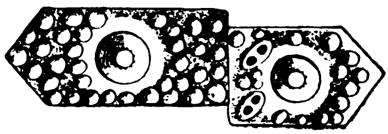


FIG. 4. × 19

ZEUGLOPLEURUS ROWEI, GREGORY.

EXPLANATION OF FIGURES.

Fig. 1, Dr. Rowe's largest specimen, side-view × 7 diam.; Fig. 2, the same from below, × 8 diam.; Fig. 3, the apical disc of the same, × 15 diam.; Fig. 4, two of the ambital, interambulacral plates of a larger specimen (No. 75,556*a*) in British Museum (Nat. Hist.).

APPENDIX B.

By F. L. KITCHIN, M.A., Ph.D., F.G.S.

TEREBRATULINA ROWEI, n.sp.

PL. VIII, FIGS. 1-5.

Description.—The shell is small, very variable in form, and oval to bluntly triangular in outline. The length is usually greater than the breadth, but these dimensions are occasionally found to be equal in full-grown specimens. The dorsal valve often almost equals the ventral in depth, and many individuals bear a relatively inflated aspect. The maximum thickness is usually situated posteriorly to the middle, and the greatest breadth, except in some young individuals, always falls within the anterior half of the shell.

The surface is ornamented by a variable number of delicately nodose radial ribs which, with the advancing growth of the shell, increase in number by dichotomy and insertion. In the largest specimens examined (between 5 mm. and 6 mm. in length), the number of ribs at the margin of the dorsal valve varies from thirty to thirty-six. Concentric lines of growth, scarcely visible in the younger stages, sometimes give rise to the appearance of imbricating lamellæ having their edges anteriorly directed.

The dorsal valve is most inflated in its posterior half, and towards the anterior margin becomes more or less flattened, often to form a shallow median longitudinal depression widening at the front. This depression is a variable feature; it is usually weak and at times scarcely developed, and then only as a character of the adult shell, while in other cases it may be traced back to the middle of the valve in a full-grown individual.

The ventral valve occasionally shows a weak median longitudinal arching or fold towards the anterior margin, corresponding to the median depression of the dorsal valve.

The hinge-line is either straight, or more often, very gently curved. The commissure describes laterally a simple course, and in fully-grown examples becomes deflected at the front to form a shallow bow or very obtuse angle corresponding to the form of the frontal dorsal median trough.

The beak is acutely pointed and strongly incurved, but seldom so strongly as to grasp the dorsal umbo. The foramen is minute and of elongated form; the deltidial plates are obscure.

Dimensions.—

Length.	Breadth.	Depth.	
3·8	3	2 mm.	From the *Uintacrinus*-band.
4	3	2 ,,	
4	3·8	2·8 ,,	From the *Marsupites*-band.
5·7	5·7	3·2 ,,	
6	5	3·2 ,,	
5·5	5	3 ,,	From the zone of *Actinocamax quadratus.*
5·8	5·8	3 ,,	
6	5·5	,,	

This description is based on the examination of fifty specimens.

Distribution.—This form is confined, so far as we know, to the zones of *Marsupites testudinarius* and *Actinocamax quadratus.* In the former zone it is of common occurrence, and in the *Marsupites*-band near Brighton it is much more frequently met with than *Terebratulina striata*, Dav. (see p. 349). It appears to be rare, however, in the zone of *Actinocamax quadratus.* Its distribution as now known in the *Marsupites*-chalk is as follows: *Uintacrinus*-band and *Marsupites*-band at Margate, Seaford Head, and Dorset Coast; *Marsupites*-band at Brighton, and *Uintacrinus*-band at Seven Sisters Head (Sussex). From the zone of *Actinocamax quadratus* this form has been collected in the base of the zone at Rottingdean (Brighton), Seaford Head, Newhaven, and Paulsgrove Pit, Portsdown Hills (Hants). It has been found by Dr. H. P. Blackmore at the base, and also higher up in this same zone at East and West Harnham, near Salisbury.

Remarks.—This beautiful and characteristic form, in its general outline, in the inflation of the valves and the anterior depression of the dorsal valve, approaches most closely to *Terebratulina triangularis*, Dav.* (= *T. striata* var. *triangularis*, Ether.†). It is, however, readily distinguished from the latter by the somewhat coarser character of the ornamentation, the less prominent, more acute, and strongly-incurved beak, and by the minuteness of the foramen. Of the forms united by U. Schloenbach‡ under the name *Terebratulina rigida*, our type appears to bear most similarity to those North German occurrences included by F. A. Roemer§ under the name *Terebratula ornata*, differing, however, by the narrower, less prominent, more acutely pointed and more strongly-incurved beak. *Terebratulina rowei* cannot be confounded with that form which characterises the "zone of *Terebratulina gracilis*"; the latter is distinguished by a more delicate type of ornamentation, a weaker degree of inflation, a flatter dorsal valve, and a broader, blunter, and more strongly-incurved type of beak.

* Davidson, "Mon. Brit. Foss. Brach." vol. v, pt. iii (Appendix to Suppl.), p. 245, Pl. xviii, fig. 3, 1884 (*Palæontographical Society*).

† Etheridge, Appendix A, in Penning and Jukes-Browne, "The Geology of the Neighbourhood of Cambridge" (*Mem. Geol. Survey*), p. 148. Pl. iii, fig. 15, 1881.

‡ U. Schloenbach, Beiträge zur Paläontologie der Jura- und Kreide-Formation im nordwestl. Deutschland, II, *Palæontographica*, Bd. xiii, 6e Lief, p. 284, 1866.

§ "Verstein. des Norddeutsch. Kreidegeb," p. 40, 1841.

It must be noted that an appreciable change is observable in the dimensions attained by this shell as it is traced upwards through its vertical range. Specimens collected from the *Uintacrinus*-band are more diminutive, on the average, than those taken from the *Marsupites*-band, while a comparatively small percentage of individuals in this latter band attain to the dimensions of the few examples hitherto known from the zone of *Actinocamax quadratus*.

With regard to the affinities of the type before us, it is difficult to speak. It appears to stand isolated, and there are apparently no links to connect it with those forms which, while absent from deposits higher than the Totternhoe Stone in England, and the lower "Pläner" in North Germany, appear to approach it most closely in general habit.

It is quite a matter of doubt, indeed, in how far the actual points of similarity in outward characters, as above noted, are to be taken as indicative of relationship; and in view of the wide chronological gap separating the occurrence of these types, such characters as the latter possess in common cannot alone be taken as proof of close genetic relationship.

NOTES TO LIST OF FOSSILS.

It is felt that, while it is essential to record the zonal range of any given fossil, it is equally important to indicate the comparative frequency of its occurrence. The following abbreviations have been employed :

C. common ; R.C. rather common ; R. rare ; R.R. rather rare.

No Bryozoa are included in the list, as time does not permit one to work out the thousands of specimens in the collection, so as to show their zonal distribution. This will be done in a subsequent communication.

The free and adnate Ceriopora, and other allied forms, are not listed, partly for the same reason, and partly because there is no reliable work of reference to consult.

The Serpulæ cannot be fully recorded, as many common forms cannot be identified.

Only a few of the commonest macroscopic Foraminifera have been included. In certain zones, where flint-meal is obtainable, many of the smaller forms have been identified, but as it has been impossible to obtain even a partially complete zonal series, it is considered wiser to leave them out altogether. The same remark applies to the Ostracoda.

Asteroidea are so rarely found in coast sections in a well-preserved state that it is impossible to determine the species, or to give any idea of zonal range.

EXPLANATION OF PLATE VIII.

Terebratulina rowei.

FIGS. 1-5.—*Terebratulina rowei*, Kitchin.
FIG. 1.—A specimen from the zone of *Actinocamax quadratus* at East Harnham, Salisbury; natural size, dorsal aspect (Blackmore Collection).
FIGS. 1*a-d*.—The same, enlarged; four aspects.
FIG. 2.—A relatively broad example from the *Marsupites*-band, east of Brighton; natural size (Rowe Collection).
FIGS 2*a-d*.—The same, enlarged; four aspects. Specimens having similar form to this, with well-marked dorsal median anterior depression and inflected frontal commissure, occur also in the zone of *Actinocamax quadratus*.
FIG. 3.—An individual, probably not fully grown, from the *Marsupites*-zone, Margate; natural size (Rowe Collection).
FIGS. 3*a-d*.—The same, enlarged; four aspects. The nodose character of the ribs is well shown.
FIG. 4.—A specimen from the *Marsupites*-band, east of Brighton; natural size (Rowe Collection).
FIGS. 4*a*, *b*.—The same, enlarged.
FIG. 5.—An example from the *Uintacrinus*-band, Seven Sisters Head (Sussex); natural size (Rowe Collection).
FIGS. 5*a-d*.—The same, enlarged.

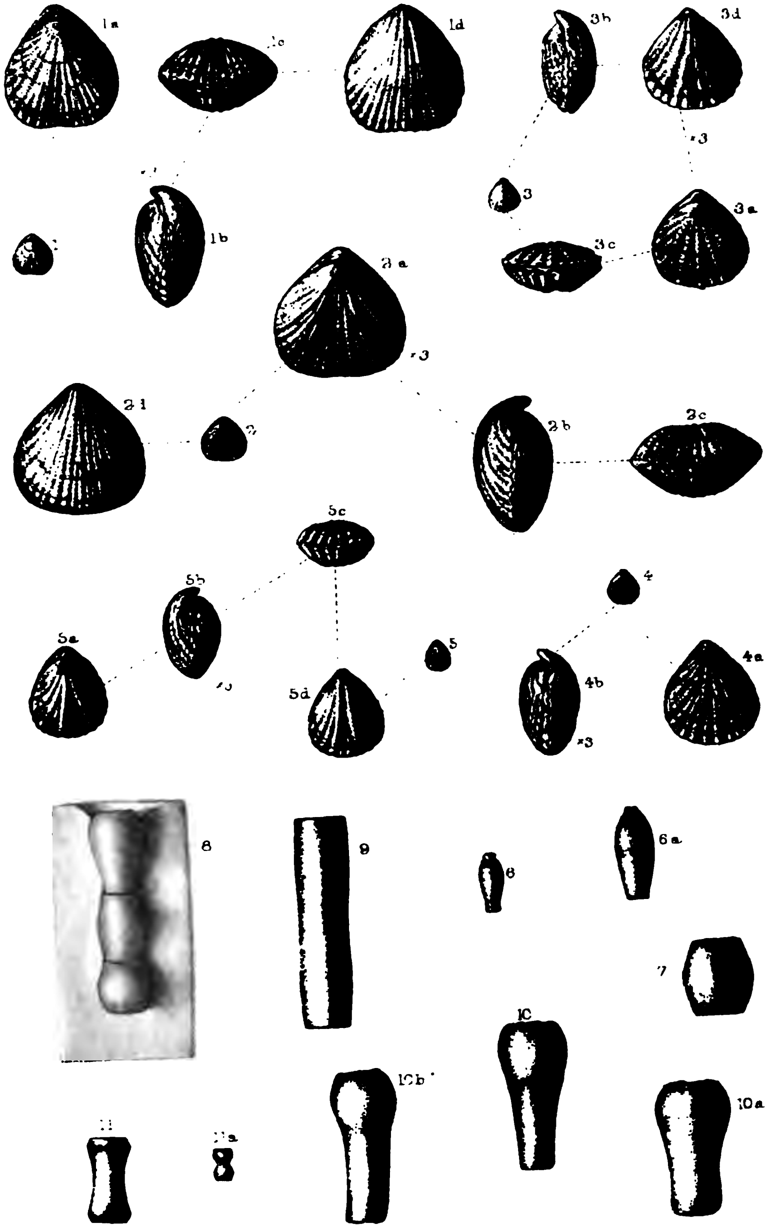
Bourgueticrinus.

FIG. 6.—A small, but well preserved, nipple-shaped head of *Bourgueticrinus*, from the *Marsupites*-band, Margate (Rowe Collection).
FIG 6*a*.—A large example of the same from the *Uintacrinus*-band, Pegwell (Rowe Collection).
FIG. 7.—A large barrel shaped ossicle of *Bourgueticrinus*, from the *Marsupites*-band, Brighton (Rowe Collection).
FIG. 8.—*Bourgueticrinus ellipticus*, with characteristic head, and barrel-shaped ossicles, from the *Micraster cor-anguinum*-zone, North Foreland, Thanet (Rowe Collection).
FIG. 9.—A long ossicle, not uncommon in the zone of *Micraster cor-anguinum*, North Foreland, Thanet (Rowe Collection).
FIG. 10.—*Bourgueticrinus ellipticus*, the characteristic head, from East Harnham, Salisbury; well up in the zone of *Actinocamax quadratus* (Blackmore Collection).
FIG. 10*a*.—The same from Paulsgrove, Portsdown Hills, near the base of the *Actinocamax quadratus*-zone (Rowe Collection).
FIG. 10*b*.—The same from extreme base of the *Actinocamax quadratus*-zone, Sussex Coast (Rowe Collection).
FIG. 11.—Small dumb-bell-shaped ossicle from the *Actinocamax quadratus*-zone, Sussex Coast (Rowe Collection).
FIG. 11*a*.—The characteristic ossicle from the *Actinocamax quadratus*-zone. The small one is merely an exaggeration of this form. Sussex Coast (Rowe Collection).

Figures 6—11a natural size.

Proc. Geol. Assoc.

Vol. XVI. Plate VIII.



West, Newman imp.

G. M. Woodward del et lith

LIST OF FOSSILS FROM THE KENT AND SUSSEX COASTS.

C. common; R.C. rather common; R. rare; R.R. rather rare.

	Zone of *Actinocamax quadratus*, Sussex.	Zone of *Marsupites testudinarius*, Thanet.	Zone of *Marsupites testudinarius*, Sussex.	Zone of *Micraster cor-anguinum*, Thanet.	Zone of *M. cor-anguinum*, St. Margaret's.	Zone of *M. cor-anguinum*, Sussex.	Zone of *M. cor-testudinarium*, Dover.	Zone of *M. cor-testudinarium*, Sussex.	Zone of *Holaster planus*, Dover.	Zone of *Holaster planus*, Sussex.	Zone of *Terebratulina gracilis*, Dover.	Zone of *Terebratulina gracilis*, Sussex.	Zone of *Rhynchonella cuvieri*, Dover.	Zone of *Rhynchonella cuvieri*, Sussex.
Wood	R.	R.R.	R.	R.R	R.	R.	R.	R.	R.	...	R.	...	...	...
Confervites	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Ramulina	R.R.	C.	C.	C.	C.	C.	R.R.	R.	R.	...	...	...	...	...
Placopsilina	R.C.	C.	C.	C.	C.	C.	R.C.	R.C.	R.C.	R.	R.C.	R.	R.C.	R.
Webbina	R.C.	R.C.	R.	R.C.	R.C.	R.C.	R.	R.	R.	...	...	...	...	...
Lituola nautiloidea, Rss.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	R.C.	R.C.
Cristellaria rotulata, Lam.	C.	C.	C.	C.	C.	C.	C.	C.	C.	R.C.	C.	R.	...	...
Flabellina cordata, Rss.	R.C.	R.C.	R.C.	C.	R.C.	R.C.	R.C.	R.C.	R.C.	R.	R.C.	...	...	...
Nodosaria zippei, Rss.	R.	R.C.	R.C.	C.	R.C.	R.C.	C.	R.C.	R.C.	R.	R.	...	...	...
Cliona cretacea, Portl.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	R.C.	R.C.	...	...
Stelletta inclusa, Hinde	...	R.	...	...	...	R.R.	R.R.	...	R.R.	...	R.C.	...	...	...
Ophiraphidites anastomans, Hinde	...	R.R.	...	R.	...	...	...	...	...	...	...	...	...	...
Stichophyma tumidum, Hinde	R.C.	C.	R.C.	C.	R.C.	R.C.	R.	R.	R.	...	R.	...	...	...
Ragadinia sulcata, Hinde	...	...	...	...	...	...	...	...	...	...	R.	...	...	...
Pachinion scriptum, Römer	...	C.	R.	C.	R.	R.C.	R.R.	R.	R.	...	R.	...	R.	...
Doryderma ramosum, Mant.	C.	R.C.	C.	C.	C	C.	R.C.	R.C.	R.C.	R.	R.	...	...	...
Heterostinia obliqua, Benett	C.	C.	C.	C.	C.	C.	C.	C.	C.	R.C.	C.	R.	R.	...
Siphonia königi, Mant.	R.C.	C.	C.	C.	C.	C.	R.C.	R.C.	R.C.	...	R.	...	...	...

LIST OF FOSSILS FROM THE KENT AND SUSSEX COASTS.—*Continued.*

	Zone of *Actinocamax quadratus*, Sussex.	Zone of *Marsupites testudinarius*, Thanet.	Zone of *Marsupites testudinarius*, Sussex.	Zone of *Micraster cor-anguinum*, Thanet.	Zone of *M. cor-anguinum*, St. Margaret's.	Zone of *M. cor-anguinum*, Sussex.	Zone of *M. cor-testudinarium*, Dover.	Zone of *M. cor-testudinarium*, Sussex.	Zone of *Holaster planus*, Dover.	Zone of *Holaster planus*, Sussex.	Zone of *Terebratulina gracilis*, Dover.	Zone of *Terebratulina gracilis*, Sussex.	Zone of *Rhynchonella cuvieri*, Dover.	Zone of *Rhynchonella cuvieri*, Sussex.
Pholidocladia ramosus, Hinde	R.C.	C.	R.	C.	R.C.	R.C.	R.R.	R.R.	R.	...	R.	...	...	...
Plinthosella compacta, Hinde	C.	C.	C.	C.	C.	C.	C.	C.	R.C.	R	R.	...	...	...
Plinthosella squamosa Zitt.	R.C.	R.	R.	R.C.	R.	R.	R.	R.	R.	...	...	...	...	...
Plinthosella nodosa, Hinde	...	R.	...	R.	...	...	...	...	...	...	...	...	...	...
Craticularia fittoni, Mant.	...	...	...	...	...	...	R.	...	R.R.	R.R.	C.	R.C.	R.C.	R.
Guettardia stellata, Mich.	R.C.	R.R.	R.R.	R.C.	R.R.	R.R.	R.C.	R.C.	C.	R.C.	C.	R.C.	R.C.	R.
Coscinopora infundibuliformis, Goldf.	C.	C.	C.	C.	C.	C.	R.C.	R.C.	R.	...	...	...	...	...
Porochonia simplex, T. Smith	R.C.	C.	R.C.	R.	R.	R.	...	...	...	...	...	...	...	...
Verrucocœlia tubulata, T. Smith	...	R.R.	...	R.R.	...	...	...	...	...	...	...	...	...	...
Leptophragma murchisoni, Goldf.	R.C.	C.	R.C.	C.	C.	R.C.	R.C.	R.C.	R.R.	...	R.R.	...	...	...
Toulminia sp.	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Ventriculites convolutus, Hinde...	R.C.	R.C.	R.	R.C.	R.R.	R.	...	...	...	...	...	...	...	...
Ventriculites cribrosus, Phill.	R.C.	C.	R.C.	C.	R C.	R.C.	R.C.	R.C.	R.C.	R.	R.	...	R.	...
Ventriculites decurrens, T. Smith	C.	C.	C	C.	C.	C.	C.	C.	R.C.	R.R.	R.C.	R.	R.	...
Ventriculites impressus, T. Smith	R.C.	C.	R.C.	C.	R.C.	R.C.	R.C.	R.C.	C.	R.C.	R.C.	R.	R.	...
Ventriculites infundibuliformis, S. Woodw. ...	R.	R.C.	R.	R.C.	R.	R.	R.	R.	R.	R.	R.	...	...	...
Ventriculites mammillaris, T. Smith	R.	R.	R.	R.	...	...	R.C.	R.C.	C.	R.C.	R.R.	...	R.	...
Ventriculites radiatus, Mant.	C.	C.	C.	C.	C.	C.	R.C.	R.C.	R.C.	R.C.	R.C.	R.	R.	...
Polyblastidium racemosum, T. Smith	...	R.	...	R.	...	...	...	...	...	...	...	...	...	...
Cephalites benettiæ, Mant.	...	...	...	...	...	...	R.	...	R.C.	...	C.	...	R.C.	...
Cephalites longitudinalis, T. Smith	...	R.	...	R.	...	...	...	...	C.	...	C.	...	R.C.	...

Cephalites catenifer, T. Smith	...	R.	...	...	...	...	...	...	...	...	...	..	...	...
Placotrema cretaceum, Hinde	...	R.	...	R.	...	...	R.	...	R.	...	...	...	...	...
Plocoscyphia convoluta, T. Smith	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C	C.	C	R.C
Plocoscyphia labrosa, T. Smith	...	R.	...	R.	R.	R.	R.C.	R.C	R.C.	R.C	C	R.C	C.	R.C
Camerospongia subrotunda, Mant.	...	...	...	...	...	...	...	...	R	...	...	...	...	...
Camerospongia aperta, Hinde	...	...	...	...	...	...	...	...	R.	...	...	.	..	..
Camerospongia capitata, T. Smith	...	...	...	...	...	...	...	...	...	...	R	...	R	.
Elasmostoma scitulum, Hinde	...	...	...	...	...	...	...	R	...	...	...	...	...	..
Pharetrospongia strahani, Sollas	C.	C.	C.	C	C.	C.	R.C	R.C.	R.C.	R.R.	R.	...	..	...
Porosphaera globularis, Phil.*	C.	C.	C.	C.	C.	C.	C.	C	C.	C.	R.C.	R.C	R.C	R.C
Porosphaera pileolus, Lam.	C.	C.	C.	C.	C.	C.	R.R.	R.R	R.R	R.	...	..	...	.
Porosphaera woodwardi, Carter	C.	C.	C.	C.	R.R	R.C.	R.	R	R.	...	...	..	...	..
Parasmilia centralis, Mant.	C.	C.	C.	C.	C	C.	R.C	R.C	R.R	R	R	..	P	...
Parasmilia centralis var. *gravesana*, E. & H.	...	R.	...	C	...	...	...	...	...	...	...	...	...	..
Parasmilia granulata, Duncan	...	R.C.	...	R.C.	...	...	...	...	...	...	...	...	...	...
Parasmilia cylindrica, E. & H.	...	...	...	R.R.	..	...	...	...	...	...	...	...	...	...
Parasmilia mantelli, E. & H.	...	...	...	R.R.	...	...	...	...	...	...	...	..	...	..
Parasmilia fittoni, E. & H.	C.	C.	R.R	...	...	...	...	...	...	...	...	...	..	...
Coelosmilia laxa, E. & H.	C.	R.	...	...	...	...	...	...	...	...	...	...	...	...
Caryophyllia cylindracea, Rss.	...	R.C.	...	...	...	...	...	...	...	...	...	...	...	...
Onchotrochus serpentinus, Duncan	...	...	...	C.	R.C.	...	...	...	...	...	...	...	...	...
Stephanophyllia michelini, Lonsd.	...	R.	...	R.	...	...	...	...	...	...	...	...	...	...
Epiphaxum auloporoides, Lonsd.	...	R.C.	R.C	C.	R.C.	C.	R.C.	R.C	R.R	R	...	...	...	...
Axogaster cretacea, Lonsd.	C.	C.	C.	C.	C.	C	R	...	...	...	..	...	...	..
Bourgueticrinus	C.	C.	C.	C.	C.	C	C.	C.	C.	C.	R.C.	R.C.	R.R	R.R.
Pentacrinus	...	R.R.	R.	R.R.	R.	R.	R	R.	C	C.	R.C	R.C.	R.R	R
Marsupites testudinarius, Mant.	...	C.	C.	...	...	...	...	...	...	...	...	...	...	...
Uintacrinus	...	C.	C.	...	...	...	...	...	...	...	...	...	...	...
Antedon perforata, Carp.	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Antedon lundgreni, Carp.	...	R.	...	...	...	...	...	...	...	...	...	...	...	...

* According to Dr. G. J. Hinde, *Quart. Journ. Geol. Soc.*, vol. lvi, 1900, p. 57, *Porosphaera*, Steinmann, is a calcisponge, belonging to the division of the Lithonina.

LIST OF FOSSILS FROM THE KENT AND SUSSEX COASTS.—*Continued.*

	Zone of *Actinocamax quadratus*, Sussex.	Zone of *Marsupites testudinarius*, Thanet.	Zone of *Marsupites testudinarius*, Sussex.	Zone of *Micraster cor-anguinum*, Thanet.	Zone of *M. cor-anguinum*, St. Margaret's.	Zone of *M. cor-anguinum*, Sussex.	Zone of *M. cor-testudinarium*, Dover.	Zone of *M. cor-testudinarium*, Sussex.	Zone of *Holaster planus*, Dover.	Zone of *Holaster planus*, Sussex.	Zone of *Terebratulina gracilis*, Dover.	Zone of *Terebratulina gracilis*, Sussex.	Zone of *Rhynchonella cuvieri*, Dover.	Zone of *Rhynchonella cuvieri*, Sussex.
Antedon striata, Carp.	...	...	...	...	...	...	R.	R.	...	...	...	...	...	...
Asteroidea...	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	R.R.	R.R.	R.R.	R.R.
Ophiura	R.	R.R.	...	R.	R.	...	...	...	...	...	R.R.	R	...	...
Oreaster obtusus, Forbes...	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Mitraster uncatus, Forbes	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Mitraster parkinsoni, Forbes	...	...	...	R.	...	...	...	...	...	...	...	...	...	...
Cidaris sceptrifera, Mant.	R.R.	C.	R.C.	C.	R.C.	C.	R.C.	R.C.	R.R.	R.R.	...	...	...	...
Cidaris clavigera, König...	R.R.	C.	R.C.	C.	R.C.	C.	R.C.	C.	R.C.	C.	R.R.	R.R.	R.R.	R.
Cidaris perornata, Forbes	...	R.R.	...	C.	C.	C.	R.C.	R.R.	R.R.	R.	R.	...	R.	...
Cidaris hirudo, Sorig.	R.C.	C.	R.C.	C.	R.C.	C.	R.C.	R.C.	R.C.	R.	R.C.	R.C.	R.C.	R.C.
Cidaris serrifera, Forbes	...	...	...	R.	R.	R.	C.	C.	C.	C.	C.	R.C.	R.R.	R.
Cyphosoma königi, Mant.	R.R.	R.C.	R.C.	R.C.	R.C.	R.C.	R.	R.	...	R.	...	...	...	...
Cyphosoma corollare, Klein	...	R.	...	R.C.	R.	R.	...	...	...	...	...	...	...	...
Cyphosoma spatuliferum, Forbes	...	R.	...	R.C.	R.	R.	...	...	...	...	...	...	...	...
Cyphosoma radiatum, Sorig.	R.	R.	...	R.	...	R.	R.C.	R.C.	C.	C.	R.C.	R.R.	...	...
Salenia granulosa, Forbes	R.	R.R.	R.	R.	...	R.	R.C.	R.R.	R.C.	R.	R.R.	R.	R.C.	...
Salenia geometrica, Ag.	...	R.R.	...	...	...	...	...	...	...	...	...	...	...	...
Zeuglopleurus rowei, Gregory	...	R.R.	...	...	R.	...	...	...	...	...	...	...	...	...
Glyphocyphus radiatus, Hoening.	...	...	...	...	...	...	...	...	...	...	...	...	R.R.	R.
Echinocorys vulgaris, Breyn.	C.	C.	C.	C.	R.C.	C.	C.	C.	C.	C.	...	R.	...	...
Echinoconus conicus, Breyn.	...	C.	C.	C.	R.C.	C.	R.	R.	...	...	...	...	...	...

Echinoconus globulus, Desor	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Echinoconus subrotundus, Mant.	...	...	...	...	...	...	...	...	...	...	R.	R.	R.C.	R.
Echinoconus castanea, Brongn.	...	...	...	...	...	...	...	...	...	...	...	...	R.C.	...
Discoidea dixoni, Forbes...	...	...	...	...	...	...	...	...	R.	R.	R.C.	R.	C.	R.
Micraster cor-anguinum (group), Leske ...	R.	C.	C.	C.	R.C.	R.C.	...	...	...	...	...	...	...	...
Micraster cor-anguinum var. *latior*	...	R.C.	R.C.	C.	R.C.	R.C.	...	...	...	...	...	...	...	...
Micraster præcursor (group)	...	...	...	...	R.C.	R.C.	C.	C.	C.	C.	...	...	...	...
Micraster cor-testudinarium (group), Goldf. ...	...	...	...	...	R.C.	R.C.	R.C.	R.C.	R.C.	R.C.	...	...	...	...
Micraster leskei, Desm.	...	...	...	...	...	...	...	...	R.C.	R.C.	R.	...	...	...
Micraster cor-bovis, Forbes	...	...	...	...	...	...	...	...	R.C.	R.	R.C.	R.	R.	...
Epiaster gibbus, Lam.	...	R.	...	R.	R.	R.	R.	...	...	...	...	...	...	...
Infulaster rostratus, Forbes	...	R.	...	R.	R.	R.	...	...	...	...	...	...	...	...
Hemiaster minimus, Ag.	...	...	...	...	...	...	R.	R.	R.	R.	R.C.	R.	R.C.	R.
Holaster planus, Mant.	...	...	...	...	...	...	R.	R.	C.	R.C.	R.R.	R.	R.	...
Holaster placenta, Ag.	R.	...	R.	...	R.	R.	C.	C.	C.	C.	R.C.	R.R.	R.	...
Cardiaster ananchytis, Leske	...	...	...	...	...	...	R.	...	R.	...	...	...	...	...
Cardiaster pygmæus, Forbes	...	...	...	...	...	...	R.	...	...	...	R.C.	R.	C.	R.
Cardiaster (Offaster) pillula, Lam.	C.	R.	...	...	...	...	...	...	...	...	...	...	...	...
Serpula ampullacea, Sby.	C.	C.	C.	C.	R.C.	C.	R.C.	R.C.	R.R.	R.	R.	...	...	...
Serpula fluctuata, Sby.	R.C.	R.C.	R.C.	C.	C.	C.	C.	C.	C.	R.	R.	...	...	...
Serpula gordialis, Schl.	C.	C.	C.	C.	C.	C.	C.	C.	C.	R.C.	R.	...	...	...
Serpula granulata, Sby.	R.R.	R.R.	R.	R.	...	R.	R.R.	R.R.	R.	...	R.	...	...	...
Serpula ilium, Sby.	C.	C.	R.C.	R.C.	R.C.	R.C.	C.	C.	C.	C.	R.R.	R.	...	...
Serpula macropus, Sby.	R.R.	R.R.	R.	R.R.	R.	R.	R.C.	R.C.	R.C.	R.	...	...	...	...
Serpula plana, S. Woodw.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	R.
Serpula plexus, Sby.	R.C.	R.C.	R.C.	C.	R.C.	R.C.	R.C.	R.C.	R.C.	R.	R.	...	...	...
Serpula turbinella, Sby.	C.	C.	R.C.	R.C.	R.C.	R.C.	R.	...	...	...	...	...	...	...
Crania parisiensis, Defr....	C.	C.	C.	C.	C.	C.	R.C.	R.C.	...	...	...	...	...	...
Crania egnabergensis var. *striata*, Retz. ...	R.C.	R.C.	R.R.	R.C.	R.	R.	R.C.	R.C.	C.	R.C.	R.	...	...	...
Thecidea wetherelli, Morris	C.	C.	C.	C.	C.	C.	...	...	...	...	...	...	...	...
Kingena lima, Defr.	...	C.	R.C.	R.C.	R.	R.	...	...	...	...	...	...	...	...
Terebratulina striata, Dav.	R.C.	R.C.	R.C.	C.	R.C.	R.C.	R.C.	R.C.	R.R.	R.R.	R.R.	...	R.	R.

LIST OF FOSSILS FROM THE KENT AND SUSSEX COASTS—*Continued.*

	Zone of *Actinocamax quadratus*, Sussex.	Zone of *Marsupites testud.narius*, Thanet.	Zone of *Marsupites testudinarius*, Sussex.	Zone of *Micraster cor-anguinum*, Thanet.	Zone of *M. cor-anguinum*, St. Margaret's.	Zone of *M. cor-anguinum*, Sussex.	Zone of *M. cor-testudinarium*, Dover.	Zone of *M. cor-testudinarium*, Sussex.	Zone of *Holaster planus*, Dover.	Zone of *Holaster planus*, Sussex.	Zone of *Terebratulina gracilis*, Dover.	Zone of *Terebratulina gracilis*, Sussex.	Zone of *Rhynchonella cuvieri*, Dover.	Zone of *Rhynchonella cuvieri*, Sussex.
Terebratulina gracilis, Schl.	...	...	...	...	...	...	R.	...	C.	R.C.	C.	C.	R.	...
Terebratulina rowei, Kitchin	R.	C.	C.	...	...	...	...	...	...	...	...	...	...	...
Terebratula semiglobosa, Sby.	R.R.	R.	...	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	R.R.
Terebratula carnea, Sby.	...	...	...	R.	...	...	R.R.	R.R.	C.	C.	R.C.	R.R.	R.	...
Rhynchonella limbata, Schl.	R.C.	R.	...	...	...	...	C.	R.	...	...	...	...	...	...
Rhynchonella reedensis, Eth.	C.	C.	C.	C.	C.	C.	C.	C.	R.C.	R.C.	R.C.	R.R.	R.	...
Rhynchonella cuvieri, d'Orb.	...	...	...	...	...	...	R.	R.	R.C.	R.R.	C.	C.	C.	C.
Rhynchonella woodwardi, Dav.	...	...	...	...	...	...	...	...	...	...	R.	...	...	...
Rhynchonella plicatilis, Sby.	C.	R.	C.	...	...	...	R.	...	C.	C.	...	...	...	...
R. plicatilis var. *octoplicata*. Sby.	C.	R.	R.C.	...	...	...	...	...	C.	C.	...	...	...	...
Pecten cretosus, Defr.	R.C.	C.	R.C.	C.	R.C.	R.C.	R.C.	R.C.	R.C.	R.R.	R.	...	R.	...
Janira quinque-costatus, Sby.	C.	C.	C.	C.	C.	C.	R.C.	R.C.	R.C.	R.R.	R.	...	...	...
Janira quadri-costatus, Sby.	...	...	...	R.	...	...	...	...	...	...	...	...	...	...
Janira dutemplei, d'Orb.	R.	R.	...	R.	...	...	...	...	...	...	...	...	...	...
Spondylus spinosus, Sby....	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	R.C.	R.	...
Spondylus dutempleanus, d'Orb....	C.	C.	C.	C.	R.C.	R.C.	R.R.	R.	...	...	R.	...	...	R.
Spondylus latus, Sby.	C.	C.	C.	C.	C.	C.	C.	C.	R.C.	R.C.	R.	R.	R.	...
Spondylus royanus, d'Orb.	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Lima hoperi, Mant.	R.R.	C.	R.C.	R.C.	R.C.	R.C.	R.C.	R.C.	R.	...	...	...	...	...

Lima pectinata, d'Orb.	„	...	..	..	...	..								
Lima granosa, Goldf.	...	„	„	„	...	„								
Lima mantelli, Brongn.	...	„	..	„										
Ostrea vesicularis, Lam.	„	„	„	„	„	„	„	„	„	„	„	„	„	
Ostrea hippopodium, Nils.	„	„	„	„	„	„	„	„	„	„	„	„	„	
Ostrea semiplana, Sby.	„	„	„	„	„	„	„	„	„	„	„	„		
Ostrea normanniana, d'Orb.	„	„	„	„	„	„	„	„	„	„	„	„	„	„
Ostrea wegmanniana, d'Orb.	„	„	„	.										
Ostrea curvirostris, Nils.	„	„	..	.										
Ostrea lateralis, Nils.	„	„	„	„	„	„	„	„	„	„	„			
Ostrea lateralis var. *striata*, Nils.	„	...	.	..	.	.								
Exogyra haliotoidea, Lam.	...	...	...	„										
Ostrea acutirostris, Nils.	...	„	...	„										
Ostrea alaeformis, S. Woodw.	„	„	„	„	.		.							
Hipponyx	...	„	..	„	.									
Plicatula sigillina, Woodw.	„	„	„	„	„	„	„	„	„	„	„	„	„	„
Plicatula barroisi, Peron	...	„	„	„	„	„	„	„	„	„	„			
Inoceramus brongniarti, Sby.	...	...	..	..	...		„		„	„	„			
Inoceramus cuvieri, Sby.	„	„	„	„	„	„	„	„	„	„	„	„	„	„
Inoceramus involutus, Sby.	...	...	...	„	„	„	„	„						
Inoceramus labiatus, Schl.	...	...	...	...	..	.	„		„	„	„	„	„	„
Inoceramus sp.*	...	..	...	...	..	.	„		„	„	„			
Avicula sp.	...	„	...	...	...	.	...							
Trapezium trapezoidale, Roemer	...	...	...	...	...	..	.		„					
Pholadites mortoni, Mant.	...	„	...			..							„	
Teredo amphisbaena, Goldf.	„	„	„	„	„	„	„	„	„		„			
Trochus schlüteri Woods	...	...	...	...	...	..	...		„					
Pleurotomaria perspectiva, Mant.	...	...	„	„	..	...	„	„	„	„	„		„	
Turbo gemmatus, Sow.	...	...	...	.	..	.	„	.	„	.	„			
Natica vulgaris, Reuss	...	..	...	..	...		.	..	„					

* Quart. Journ. Geol. Soc. vol. lii. ... H. Woods. [illegible]

LIST OF FOSSILS FROM THE KENT AND SUSSEX COASTS.—*Continued.*

	Zone of *Actinocamax quadratus*, Sussex.	Zone of *Marsupites testudinarius*, Thanet.	Zone of *Marsupites testudinarius*, Sussex.	Zone of *Micraster cor-anguinum*, Thanet.	Zone of *M. cor-angui-num*, St. Margaret's.	Zone of *M. cor-anguinum*, Sussex.	Zone of *M. cor-testu-dinarium*, Dover.	Zone of *M cor-testu-dinarium*, Sussex.	Zone of *Holaster planus*, Dover.	Zone of *Holaster planus*, Sussex.	Zone of *Terebratulina gracilis*, Dover.	Zone of *Terebratulina gracilis*, Sussex.	Zone of *Rhynchonella cuvieri*, Dover.	Zone of *Rhynchonella cuvieri*, Sussex.
Cerithium saundersi, Woods	...	...	...	...	...	...	...	...	R.	...	...	...	...	...
Aporrhais mantelli, Gardn.	...	...	...	...	...	...	...	...	R.	...	...	...	...	...
Aporrhais sp.	...	...	R.	...	...	...	...	...	...	...	R.	...	...	...
Avellana ? *humboldti*, Müller	...	...	...	...	...	...	...	...	R.R.	...	...	...	...	...
Dentalium ? *turonense*, Woods	...	...	...	...	...	...	...	...	R.R.	...	...	...	...	...
Heteroceras reussianum, d'Orb.	...	...	...	...	...	...	...	...	R R.	...	...	...	...	...
Nautilus sublævigatus, d'Orb.	...	...	...	...	...	...	...	...	R.	...	...	...	...	...
Baculites bohemicus, Fritsch	...	...	...	...	...	...	...	...	R.C.	...	...	...	...	...
Scaphites geinitzi, d'Orb.	...	...	...	...	...	...	...	...	R C.	...	...	...	...	...
Ammonites peramplus, Mant.	...	...	...	...	...	...	...	...	R.C.	...	R.	...	R.C.	R.
Ammonites leptophyllus, Sharpe	R.C.	C.	C.	...	...	...	...	...	...	...	...	...	...	...
Ammonites catinus, Mant.	...	...	...	...	...	...	...	...	...	...	...	...	R.	...
Ammonites cunningtoni, Sharpe	...	...	...	...	...	...	...	...	...	...	...	...	R.	...
Actinocamax merceyi, Mayer-Eymer	R.R.	R.C.	R.R.	...	...	...	...	...	..	...	...	...	...	...
Actinocamax verus, Miller	...	C.	R.	...	...	...	...	...	...	...	...	...	...	...
Enoploclytia leachii, Mant.	R.	R.C.	R.	R.	R.	R.	R.	...	R.	R.	...	...	...	...
Pollicipes glaber, Röm.	R.	R.C	R.	R.	...	R.	...	...	...	...	...	...	...	...
Scalpellum fossula, Darw.	R.R.	R.C.	R.R.	R.R.	R.	R.	R.	R.	...	...	...	...	...	...
Scalpellum maximum, Sby.	R.R.	R.C.	R.R.	R.R.	R.	R.R.	R.	R.	R.	...	R.	...	...	...

LIST OF FOSSILS FROM THE KENT AND SUSSEX COASTS.—*Continued.*

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Lewdon	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Portheus	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Cimolichthys lewesiensis, Leidy	R.R.	R.R.	...	R.	...	...	...	...	...	...	...	...	...	...
Enchodus lewesiensis, Mant.	R.R.	R.C.	R.	R.R.	...	R.	R.	...	...	...	...	...	...	...
Protosphyræna ferox, Leidy	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Beryx	C.	C.	C.	C.	R.C	C.	R.C.	R.C.	R.C.	R.C.	R.	...	...	...
Macropoma mantelli, Ag.	R.	R.R.	R.	R.	...	...	...	...	...	...	...	...	...	...
Corax falcatus, Ag.	C.	C	C.	C.	R.C.	C.	R.R.	R.R.	R.R.	...	...	...	...	...
Corax pristodontus, Ag.	R.	R.	...	R.	...	...	...	...	...	...	...	...	...	...
Corax affinis, Ag.	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Lamna appendiculata, Ag.	R.R.	C.	R.C	C.	R.R.	R.C.	R.R.	R.R.	R.R.	R.	R.R.	...	R.	...
Scapanorhynchus subulatus, Ag.	...	R.	...	R.	...	...	...	...	...	...	...	...	...	...
Oxyrhina mantelli, Ag.	R.R.	R.C.	R.R.	R.C.	...	R.R.	R.	R.	R.	...	R.	...	...	...
Notidanus microdon, Ag.	...	R.	...	R.	...	...	...	...	...	...	...	...	...	...
Belonostomus ? cinctus, Ag.	...	R	...	...	...	...	...	...	...	...	...	...	...	...
Ptychodus polygyrus, Ag.	...	R.	...	...	...	...	R.	...	R.	...	R.C.	...	R.C.	...
Ptychodus mammillaris, Ag.	...	...	...	...	...	...	R.	R.	R.	...	R.C.	...	R.C.	...
Anomaeodon angustus (Ag.)	...	R.	...	...	...	...	...	...	...	...	...	...	...	...

NOTES ON THE CLIFF SECTIONS.

By C. Davies Sherborn.

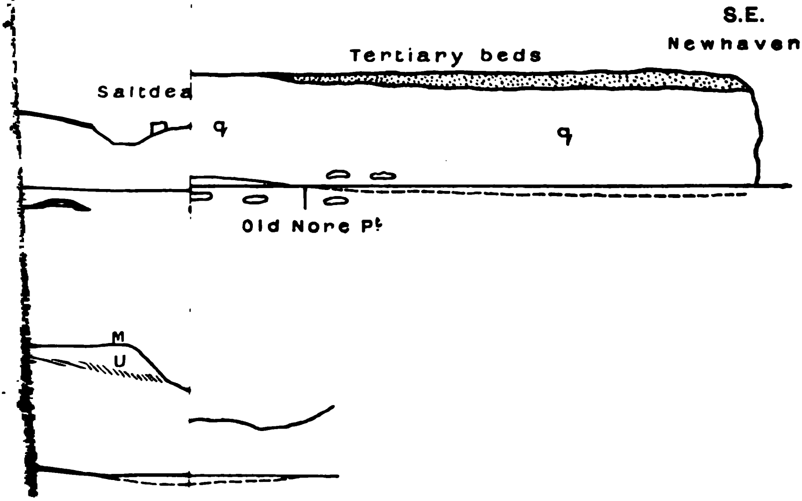
The sections here reproduced, show the various zones of the White Chalk as they are seen on the cliff-face by the observer, without regard to any dip that may exist landwards or seawards. They are also given without any regard to the various bluffs that exist and break the continuity of the general direction.

In Section 1 (Brighton to Eastbourne) the $1\frac{3}{4}$ miles omitted, near Portobello, show practically no features of interest, and the first important bluff we meet with is at the west corner of Friar's Bay, while the second is at Old Nore Point. The small exposure mentioned at p. 335, as between Seaford and Newhaven, is not shown. Further Point occurs just about the letter "a" in Seaford Head, and from there into Eastbourne there is but one noteworthy bluff in the cliff-face, and that occurs just to the east of Beltout.

In Section 2 (Dover to Kingsdown) a good east and west face will be found at Ness Point, St. Margaret's, and further information as to dip can be gained at Leather Court Point, to the north.

In Section 3 the upper section runs from west to east at first, and afterwards, from the omitted four miles to the North Foreland, from south to north. In the lower section from the North Foreland to White Ness, the general direction is south to north, and the rest, generally, east to west. At White Ness, from the letter "U" to the Point, the section is at right angles to that seen in the cliff-face at the Lifeboat slip, while at the Target and at several places between Margate and Gore End, similar faces can be seen and studied.

PLATE IX.



'G THE CLIFF-FACE FROM BRIGHTON TO EASTBOURNE.

'es-zone.

ne.

s.

H.sub. *Holaster subglobosus*-zone (Chalk Marl, Chloritic Marl, and Upper Greensand are visible on the shore).

B. Bryozoan bed in the *Actinocamax quadratus*-zone.

D. Stairway to Telscombe.

A ⊂⊃ *Ammonites* (*leptophyllus* group).

G. Groynes.

S. Sewer near Portobello.

: 3 inches = 1 mile ; vertical scale indicated.

THE NATURAL HISTORY OF PHOSPHATIC DEPOSITS.

By J. J. H. TEALL, M.A., F.R.S.

(Presidential Address delivered February 2nd, 1900.)

GREAT interest centres round the element phosphorus in consequence of the part it plays in the organic world, not only as an important constituent of the hard parts of many animals and of the seeds of plants, but also as forming an essential component of living matter. From the earliest appearance of life upon the globe down to the present day, there has been a constant circulation of phosphorus between organic and inorganic nature. From the rocks, in which it is almost always present, though in small quantities, it passes into the soil and into the waters of rivers, lakes, and seas. It is taken up by plants, handed on to animals, and from these it may again pass either directly or indirectly to the solid crust. I ask your attention to the processes involved in this circulation, and to some of the geological consequences which follow from it.

Phosphates of Igneous Rocks and Mineral Veins.

Of the various phosphatic minerals apatite is by far the most abundant, and has long been recognised as the principal source of the phosphorus found in the sedimentary rocks and in the organic world. It occurs as definite crystals, less frequently as more or less rounded grains, in all varieties of igneous rocks; but is more common in the basic than in the acid varieties.

Among the British rocks, exceptionally rich in apatite, may be mentioned the mica-traps of the West of England and the Southern Uplands of Scotland; also a peculiar group of hornblende-diabases occurring at Wearde, Ernsettle, and other places in the Plymouth district. The largest apatites I have ever seen in normal igneous rocks occur in hornblende- and mica-andesites from Bail Hill, near Sanquhar. One of these measures $5 \times 2\frac{1}{2}$ mm., and is considerably larger than the porphyritic felspars occurring in the same rock.

The apatites of igneous rocks have undoubtedly crystallised out of the magma. They occur as inclusions in all the essential minerals, and therefore belong to the earliest phases of consolidation. Under these circumstances it is somewhat surprising that, so far as I am aware, apatite has never been produced synthetically by crystallisation from artificial rock-magmas. It has, however, been observed in lead slags by Mr. Hutchings [20] and Professor Vogt.[42]

been forced upwards along the cracks in the already consolidated upper part of the magma, or along the planes of least resistance in the surrounding rocks, either in the form of a solution or, more probably, as a dense gaseous substance at a temperature about its critical point and therefore under great pressure. Professor Vogt's theory of the origin of the apatite-veins by a kind of high pressure solfataric (pneumatolytic) action may at least be regarded as a useful working hypothesis. It is an expansion of the ideas formulated by the illustrious author of "Études Synthétiques de Géologie Expérimentale."

Modern Deposits.

The apatites of igneous rocks and mineral veins are doubtless the principal source of the phosphorus of the sedimentary rocks, and of the organic world, for the other phosphatic minerals of similar origin (monazite, xenotime, etc.) are too rare to have sensibly affected the supply. That they pass into solution is proved by their absence, or extreme rarity in the finer-grained sedimentary rocks which contain zircons in abundance. These two minerals occur together in igneous rocks, but the former is much more common than the latter. If the apatites were not destroyed in the process of denudation they would certainly be found in fine-grained sands, such as those of Hampstead Heath, in much greater abundance than zircon. But as Mr. Dick has pointed out they are extremely rare, and occur only as inclusions in other minerals.

The solution of apatite may be effected by water charged with carbonic acid; more readily by water containing organic acids or ammonium carbonate. Phosphorus is, therefore, present in river and sea waters; but only in small quantities. The water of the Rhine at Cologne contains rather less than one part in 1,000,000 (estimated as P_2O_5); that of the North Sea, off the coast of Norway, about ten times as much.[33] Nevertheless, it is from these very small quantities that organisms living in the water must obtain their supply of phosphorus.

If we leave out of account the very small amount of detrital apatite it is highly probable that the whole of the phosphorus found in the sedimentary rocks has been derived, either directly or indirectly, from the waters of rivers, lakes, and seas by the action of organic life.*

The once celebrated Peruvian guano furnishes an example of the formation of phosphates by the accumulation of animal remains. It was, for little now remains, an unsavoury mass made up of the excrement of sea-birds mixed with their carcasses, and

* Calcium phosphate may be deposited directly from solutions of apatite in regions where this mineral forms an important constituent of mineral veins; *e.g.*, staffellite in association with the Norwegian veins. But this scarcely requires a modification of the above statement.

LIST OF FOSSILS FROM THE KENT AND SUSSEX COASTS.—*Continued.*

	Zone of *Actinocamax quadratus*, Sussex.	Zone of *Marsupites testudinarius*, Thanet.	Zone of *Marsupites testudinarius*, Sussex.	Zone of *Micraster cor-anguinum*, Thanet.	Zone of *M. cor-anguinum*, St. Margaret's.	Zone of *M. cor-anguinum*, Sussex.	Zone of *M. cor-testudinarium*, Dover.	Zone of *M. cor-testudinarium*, Sussex.	Zone of *Holaster planus*, Dover.	Zone of *Holaster planus*, Sussex.	Zone of *Terebratulina gracilis*, Dover.	Zone of *Terebratulina gracilis*, Sussex.	Zone of *Rhynchonella cuvieri*, Dover.	Zone of *Rhynchonella cuvieri*, Sussex.
Leiodon	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Portheus	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Cimolichthys lewesiensis, Leidy	R.R.	R.R.	...	R.	...	...	...	...	...	...	...	...	...	...
Enchodus lewesiensis, Mant.	R.R.	R.C.	R.	R.R.	...	R.	R.	...	...	...	...	...	...	...
Protosphyraena ferox, Leidy	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Beryx	C.	C.	C.	C.	R.C.	C.	R.C.	R.C.	R.C.	R.C.	R.	...	...	...
Macropoma mantelli, Ag.	R.	R.R.	R.	R.	...	...	...	...	...	...	...	...	...	...
Corax falcatus, Ag.	C.	C.	C.	C.	R.C.	C.	R.R.	R.R.	R.R.	...	...	...	...	...
Corax pristodontus, Ag.	R.	R.	...	R.	...	...	...	...	...	...	...	...	...	...
Corax affinis, Ag.	...	R.	...	...	...	...	...	...	...	...	...	...	...	...
Lamna appendiculata, Ag.	R.R.	C.	R.C.	C.	R.R.	R.C.	R.R.	R.R.	R.R.	R.	R.R.	...	R.	...
Scapanorhynchus subulatus, Ag.	...	R.	...	R.	...	...	...	...	...	...	...	...	...	...
Oxyrhina mantelli, Ag.	R.R.	R.C.	R.R.	R.C.	...	R.R.	R.	R.	R.	...	R.	...	...	...
Notidanus microdon, Ag.	...	R.	...	R.	...	...	...	...	...	...	...	...	...	...
Belonostomus ? cinctus, Ag.	...	R	...	...	...	...	...	...	...	...	...	...	...	...
Ptychodus polygyrus, Ag.	...	R.	...	...	...	...	R.	...	R.	...	R.C.	...	R.C.	...
Ptychodus mammillaris, Ag.	...	...	...	...	...	...	R.	R.	R.	...	R.C.	...	R.C.	...
Anomaeodon angustus (Ag.)	...	R.	...	...	...	...	...	...	...	...	...	...	...	...

per cent. of other calcareous organisms, 6 per cent. of siliceous organic remains, including pale green casts of foraminifera, and 40 per cent. of coarse sediment (·35 mm), including quartz, felspar, garnet, black mica, and hornblende. Small glauconitic concretions containing phosphate of lime were present.

The next sounding, a little further south in 150 fathoms, also brought up green sand. The constituents were generally similar to the last, but there was a large proportion of calcareous organisms, including teeth and fragments of fish bones. The mineral particles were smaller (·2 mm.). The dredge contained glauconitic concretions, from 2 to 6 mms. in diameter, and a good many phosphatic concretions, some over 1 cm. in diameter. There was also much amorphous matter, which gave off an organic odour when heated on platinum foil ; the phosphatic nodules were found to consist of grains of quartz and glauconite, precisely similar to those occurring in the deposit, cemented by brown amorphous phosphate of lime.

The two soundings above referred to were on the edge of the Agulhas bank, the next was in deep water (1,900 fathoms) about 100 miles south-east of the bank. The bottom was of globigerina ooze. The mineral particles were much smaller both in size (·12 mm.) and amount (3 per cent.). The dredge contained many small phosphatic concretions (1 to 4 cms.) enclosing glauconite and foraminifera. These facts fully prove that phosphatic concretions are being formed at present on the bed of the sea, and that they are produced in such a way as to cement together the deposits accumulating on the sea-floor at the spot where the nodules are found.

Messrs. Murray and Renard point out, as a general result of their researches, that deposits of phosphate and glauconite are especially characteristic of the continental borders of the great ocean-basins, and that the former occur in greatest abundance where currents of different temperatures or different salinities intermingle. More or less phosphate, generally less than 1 per cent., is always present in globigerina ooze ; but it is only in special localities, where a considerable destruction of pelagic organisms may be expected to occur, that important accumulations take place.

Another observation made by the *Challenger* furnishes striking proof that the phosphate of lime separated by fishes and other organisms is dissolved in sea water. At one station in the Pacific, the dredge brought up 1,500 sharks' teeth, besides an immense number of small teeth which were not counted. Although the skeleton of the shark is only partly calcified, it contains a considerable amount of phosphate of lime. The presence of such a large number of teeth, without bones, represents, therefore, the solution of a vast amount of phosphatic matter.

Palæozoic Phosphates.

We pass on now to a review of the distribution of phosphates in the sedimentary rocks.

These phosphates vary greatly in chemical composition, but this variation is mainly due to a varying admixture of sedimentary material, such as quartz, glauconite, tests of foraminifera, etc. When allowance is made for this, there is seen to be great uniformity. The substance is mainly a tricalcic phosphate. The distribution of fluorine in the sedimentary phosphates has been made the subject of a special research by M. Carnot,[5] with the result that it is usually found to be present in proportions not very different from those of a fluor-apatite. The phosphorite deposits of the south-west of France form a notable exception to this rule, as they contain little or no fluorine. The Florida phosphates, on the other hand, often contain more fluorine than is necessary to make apatite. M. Carnot associates the presence of fluorine with the action of sea-water.

Under the microscope the phosphates are seen to be either amorphous or fibro-crystalline. The latter variety takes on stalagmitic, mammillary, and agate-like forms. The fibres give straight extinction, and are positive.

At one time it was generally held that the lower Palæozoic rocks were deficient in phosphates. This view was successfully combated by our lamented friend, Dr. Hicks,[18] in an important paper, published in the *Quarterly Journal* of the Geological Society for 1875, to which Mr. Hudleston contributed an appendix. These authors prove that phosphate-secreting organisms, such as trilobites, abounded in Cambrian times, and that the rocks themselves are by no means deficient in phosphoric acid. The same number of the *Quarterly Journal* contains a paper by Mr. Davis [13] on a remarkable bed of phosphatic nodules at the top of the Bala limestone in North Wales, which was then being worked, and to which Dr. Voelcker had directed the attention of the British Association in 1864.

The earliest known phosphatic deposits are those which occur in the Cambrian of Nuneaton (Warwickshire), New Brunswick, and Sweden. The Nuneaton deposit occurs a few feet below the *Hyolithus*-limestone. Pebbles of quartz and slate lie in a matrix containing glauconite, oxides of iron and manganese, and 14 per cent. of phosphate of lime.[25] The New Brunswick deposit, described by Mr. Matthews [29] consists of small round or oval nodules, about one half inch in diameter, set in a sandy matrix of glauconite and quartz. The nodules have always a trilobite-test or a number of fragments near the centre. Under the microscope they are seen to consist of amorphous phosphate containing fragments of trilobites (*Protolenus*), spicules of sponges, and the tests of protozoa resembling foraminifera. It is extremely interesting to note at this very early period the association of nodular

phosphates and glauconite under conditions that have been reproduced throughout the entire series of geological formations down to the present day.

Phosphatic deposits occur at many horizons in the Cambrian and Ordovician rocks of Sweden. They have been carefully studied and well described by Gunner Andersson.[1] The oldest Lower Cambrian deposit belongs to the zone of *Torrellella lævigata*. It is represented by a boulder of the basal conglomerate found on the island of Gotska Sandon. The matrix is composed of glauconite and quartz cemented by calcite. Numerous small and often fragmentary specimens of the characteristic fossil, filled with compact phosphate, occur in the matrix together with pebbles of granophyre and quartz, and nodules of phosphatic sandstone and compact phosphorite. *The quartz grains in the nodules are smaller than those in the matrix.* Andersson especially calls attention to the last mentioned fact, which appears to be not uncommon in phosphatic deposits of all ages.

The Middle and Upper Cambrian periods are represented in Sweden by the lithologically monotonous black shales, usually known as alum-shales, containing beds and lenticles of bituminous limestones. These alum-shales exhibit a rich series of palæontological zones which have been worked out in great detail by the Swedish geologists. Here and there the regular succession of black shales is broken by the occurrence of conglomeratic deposits —I use Andersson's term, but I am by no means sure that nodular deposits would not, in some cases, be more appropriate —and this phenomenon is always associated with a break in the faunal sequence. Moreover, the matrix of these conglomerates contains a mixture of faunas due, in part at least, to the wearing away of older deposits by submarine erosion.

One of the most interesting of the conglomeratic deposits is termed the *Acrothele granulata*-conglomerate. It occurs between the zones of *Paradoxides ölandicus* and *P. tessini* in the island of Oland. The matrix is composed of grains of quartz and glauconite cemented with calcite. Fragments of trilobites and other fossils occur. *Acrothele granulata* is abundant, and the two valves are generally found together. The conglomerate contains green coated pebbles of limestone apparently due to the destruction of an older deposit, but as *Acrothele granulata* occurs in these pebbles it cannot have been much older. Phosphates are present as nodules or pebbles, and also, to a certain extent, as the infilling material of the fossils in the matrix—a fact which proves that the formation of the phosphate was contemporaneous with the deposit.

Another and different mode of occurrence of phosphate is to be found at the junction of the Cambrian and Lower Silurian (Ordovician) in Nerike and Westergothland. The surface of the Cambrian limestone has been worn into pits and depressions as if

corroded by chemical action. The overlying Lower Silurian deposit is a limestone rich in glauconite containing phosphatic fragments. It descends into the hollows of the underlying floor. Corrosion phenomena are not limited to the surface of the Cambrian limestone. They occur in the phosphatic bed, and in overlying limestone; but at these higher horizons they are more tube-like and may be due to boring organisms. The phosphatic fragments are merely detached portions of the underlying floor in which the original carbonic acid has been replaced by phosphoric acid. Lower Silurian fossils occur in the matrix; Cambrian fossils in the fragments. In one case a thin crust of phosphate was observed on the surface of the underlying limestone. Almost everywhere in the Baltic region the Lower Silurian begins with glauconitic deposits which contain phosphates, especially where there are important breaks in the zonal succession.

Andersson recognises two types of phosphatic deposit in the lower Palæozoic rocks of Sweden. One, the conglomeratic, he regards as a littoral facies; the other, represented by the deposit at the base of the Ordovician in Nerike, as a shallow sea facies. The nodules and pebbles of the conglomeratic deposits consist of phosphatic sandstone or compact phosphorite—sometimes also of foreign rocks, such as quartz and granophyre. The phosphatic nodules have probably been formed by some kind of concretionary action from water charged with phosphatic matter derived from brachiopoda, such as *Acrothele* and *Obolus*, which secrete phosphate of lime in their tests.

The fact that the sand-grains in the nodules are, as a rule, smaller than those of the matrix of the conglomeratic beds suggests that the concretionary action did not take place under the conditions which finally prevailed; but it is not necessary to suppose that the nodules were washed into the littoral zone from an area of deeper water, as our author suggests. This fact might be explained by a shallowing of the sea or by an increase in current action and the consequent winnowing away of the finer matrix in which the nodules were originally formed.

In the case of the deposits at the base of the Lower Silurian in Nerike and Westergothland, little or no concretionary action has taken place. The phosphates are merely portions of the underlying limestones in which a substitution of phosphoric for carbonic acid has taken place.

I have referred to this important work by Andersson at some length because it is based on a careful study of the stratigraphical, palæontological, and petrographical characters of the deposits. It is only by a combination of these various methods of research that we can hope to work out the natural history of our sedimentary rocks; a branch of research which I recommend to any of the younger members of the Association who are looking out for work to do.

Phosphatic deposits of Lower Silurian age have recently (1896) been discovered in Tennessee, and have suddenly become of considerable commercial importance.[34] The Capitol limestone, a "granular current-formed and hence laminar limestone, showing cross-stratification" has been locally phosphatised and subsequently enriched by the leaching out of the more soluble carbonate. At what date and under what conditions the phosphatisation took place has not been ascertained.

The Upper Palæozoic rocks of this country are not known to contain any important phosphatic horizons; but this is merely a local character, for in Tennessee deposits of great interest and some commercial importance occur in the Devonian. These deposits have been described by Mr. Hayes.[17] They were worked for a few years, but have now been almost entirely abandoned for the more profitable Silurian phosphates above referred to.

At the western margin of the great Silurian inlier, which forms such a striking feature on the geological map of the State, the Devonian period is represented by only 10 or 12 ft. of strata, intercalated between the Silurian limestone below and the Carboniferous shales and limestones above.

Several feet of black carbonaceous shale, representing the edge of the Chatanooga black shale, a well marked Devonian horizon, traceable over about 40,000 square miles and attaining a thickness of several hundred feet in Virginia, separate two phosphatic horizons. The lower is formed of a bedded phosphate, the upper is a nodular deposit containing glauconite—the faithful companion of phosphate in all geological formations from the Cambrian period to the present day.

The bedded phosphates are the most valuable, the richest portion yielding from 70 to 80 per cent. of tricalcic phosphate. Four varieties are described by Hayes under the terms oolitic, compact, conglomeratic and shaly. Speaking of the oolitic variety he says:

"On close examination of the unweathered rock the constituent grains are seen to be small, round or flattened ovules, giving it an oolitic structure. The ovules are bluish black or grey with a glazed surface. Associated with them are many fragmentary casts of very small coiled shells, generally well rounded and with the same glazed surface as the ovules, so that they add to the appearance of oolitic structure. These ovules and casts are embedded in a fine grained or structureless matrix." Under the microscope the ovules and fossil casts are seen to be composed of a light amber or yellowish brown, amorphous phosphate of lime. In addition to the casts of shells there are numerous fragments of corals, and perhaps other organisms, all well rounded. It is clear from the description given by Mr. Hayes that this deposit has many points of resemblance to the phosphatic chalks and to the Tertiary phosphates of Tunis and Algeria.

The Chatanooga black shale separates the bedded phosphates from the nodular layer at the base of the Carboniferous, which is traceable as a phosphatic and glauconitic horizon over an enormous area, occurring in Eastern Tennessee, Middle Tennessee, and Arkansas. "The nodules vary in size and shape from nearly spherical bodies, ½ to 1½ inches in diameter, to irregular flattened ellipsoids sometimes 2 ft. in length, and a third or a quarter as thick. They have smooth surfaces, separating readily from the enclosing matrix, and show no external evidence of organic origin. . . . Thin sections of the nodules examined under the microscope show them to be composed chiefly of an amber-coloured amorphous substance with grains of pyrite and carbonaceous matter, and in some cases showing a concretionary structure consisting of very minute, radial, globular, and mammillary forms."

Phosphatic nodules are not limited to the well-marked layer at the top of the black shale, but occur on certain horizons in the shale itself, thus reminding one very forcibly of the relation which the Cambridge Greensand bears to the Gault.

These Devonian rocks of Tennessee furnish a striking case of the association of phosphates with areas of minimum sedimentation, accompanied in all probability, in the case of the nodular band, with a certain amount of submarine erosion. Traced towards the north-east into the folded zone of the Appalachians, the Devonian sediments swell out into an important formation, measuring hundreds and even thousands of feet in thickness.

Mesozoic Phosphates.

The phosphatic deposits of the Mesozoic period are too numerous to mention in detail. Phosphates are present in the Rhætic bone-bed. Nodules and phosphatised fossils occur in the three important argillaceous deposits belonging to the Jurassic period, the Lias, Oxford and Kimeridge Clays.

The Lower Lias, north of the Mendip Hills, about Radstock, furnishes an interesting case of the occurrence of phosphatic nodules in an area of minimum sedimentation. Mr. Tawney [38] proved that several ammonite-zones are here crowded together into a small thickness. The deposition of sediment acts on the zonal succession and on the distribution of phosphatic matter very much as a prism acts on the rays of light. It supplies a kind of dispersive power. When this is slight the zonal forms are crowded together, and the phosphates, which would otherwise be scattered through a considerable thickness of sediment, become locally concentrated.

A bed of nodules is recorded by Mr. H. B. Woodward [41] in the Middle Lias of Lincolnshire, and another occurs near the base of the Inferior Oolite (Dogger) in Yorkshire.

On the Continent phosphatic nodules have been recognised in the Upper, Middle, and Lower Lias of Lorraine. The most important deposits occur approximately on the same horizon as that at which phosphates are found at Radstock. The nodules have been microscopically examined by M. Bleicher,[3] who has proved that many, especially those of the Lower Lias, have been formed by the accumulation of phosphatic matter round sponges. They are similar to the phosphatised sponges from the Cambridge Greensand described by Prof. Sollas.

Phosphatic nodules probably occur in the Oxford Clay of this country, but I am not able to give actual instances. Mr. Newton and I have, however, described their occurrence, on this horizon, in Franz Josef Land, from the collections made by Dr. Kœttlitz during his stay there as a member of the Jackson-Harmsworth expedition. We have pointed out that some of these nodules are largely composed of minute oval bodies similar in form and size to the coprolites observed by Messrs. Strahan, Renard, and Cornet in the phosphatic chalks of England, France, and Belgium. I have since found similar bodies in a large coprolite ($3\frac{1}{2} \times 1\frac{1}{2}$ inches) with spiral groove, collected by myself many years ago from the nodular bed at the base of the Red Crag in Suffolk. This curious occurrence of coprolites within a coprolite may possibly be explained by supposing a large animal to have eaten smaller ones.*

The Kimeridge Clay also contains phosphatic concretions, and a fairly persistent bed occurs at its base in Lincolnshire and Cambridgeshire, marking the junction with the underlying Ampthill Clay.[32]

Next in order come the nodular deposits of the *Belemnites lateralis*-zone of Lincolnshire and Yorkshire, described by Mr. Lamplugh.[23, 24] These include the bed at the base of the Spilsby Sandstone in Lincolnshire, that at the base of the Speeton Clay in Yorkshire, and the interesting compound nodular band in the middle of the Speeton Clay at the top of the *B. lateralis*-zone, where a remarkable change of fauna takes place, due, in part at least, to the intermingling of northern and southern forms.

The records of the Cretaceous period contain still more important nodular deposits. There are, for example, the deposits of Wicken, Potton, and Brickhill, of Lower Greensand age, described by Brodie, Walker, Seeley, Keeping,[22] myself,[39] and others; and the remarkable Cambridge Greensand so well studied by Seeley, Fisher,[15] Sollas,[35] and Jukes-Browne.[21] Nodules also occur in the Gault and in the Chalk. A well-marked bed is

* Since this was written Mr. Allen has directed my attention to a paper by Dr. Rust, in which similar oval bodies are described as occurring in certain coprolites from the Gault (*Palæontographica*, Band xxxiv, 1887-1888, p. 184). Dr. Rust considers that two explanations are possible. The oval bodies may be either the coprolites of small animals which have been eaten by the large animal, or the casts of the follicles of the intestines of the larger animal.

found in the *Ammonites mammillatus*-zone at West Dereham in Norfolk, and Folkestone in Kent. This is one of the most widely-distributed phosphatic horizons in Europe, for it is traceable all round the northern part of the Paris basin, and is found also in the basin of the Rhone.[5]

I will not attempt to give an account of these various deposits, but content myself with some general remarks on the phosphatic nodules and the conditions under which they were probably formed. The "nodules"—I use the term in a broad and general sense—include:

(1) Casts of fossils, such as cephalopods, lamellibranchs, gasteropods, brachiopods, echinoderms, etc.

(2) Phosphatised sponges and pieces of wood.

(3) Concretionary masses.

(4) Well-rounded or sub-angular pebbles of phosphatic sandstone and compact phosphate.

(5) Bones, teeth, and occasionally coprolites of fish and saurians.

The nodules are mainly composed of phosphate of lime with only small quantities of phosphate of alumina and iron. They invariably contain more or less of the sediment which was accumulating on the sea-bed at the time of, or shortly before, their formation. This sediment may be a quartzose sand, a glauconitic sand, a loam, clay, marl, or organic ooze. It may or may not agree in composition with the matrix in which the nodules are embedded. Not unfrequently the sand-grains in the nodules are smaller than those in the matrix, and different nodules in the same bed may contain sediment of different types. Thus the nodules of the Potton deposit, so far as I have examined them, contain smaller grains than the matrix; those of the West Dereham deposit, on the other hand, contain grains of the same size as the matrix, and are, in part at least, merely phosphatic concretions in the sand.[39]

The shapes of the nodules have been determined by many causes; by the form of the original concretion, by that of the organism of which the nodule is a cast, or around which the phosphate has accumulated, and lastly by chemical corrosion or mechanical attrition. Boring organisms have also affected the forms of many nodules, a fact which clearly proves that they must have lain exposed on the sea-floor.

Mr. Lamplugh has called attention to the complex character of the nodules from the bed which occurs in the middle of the Speeton Clay. Fragmentary casts of ammonites in black phosphate are often encrusted with a brownish phosphate containing grains of quartz and glauconite. Both types of phosphate are sometimes enclosed in a grey limestone which seems also to have had a concretionary origin. All these facts point to the

conclusion that the nodule-beds represent a considerable period of time.

Much discussion has taken place as to the nature of the fossils occurring in the Cretaceous phosphatic nodules. Are they indigenous or derived? I do not propose to enter into this discussion, but I will point out that most of the so-called derived fossils belong to the age of the missing zones. This has been conclusively established by Mr. Jukes-Browne for the Cambridge Greensand, and by Mr. Lamplugh for the two coprolite beds at Speeton, and for the bed at the base of the Spilsby Sandstone.

A more careful determination of the species of other deposits will, as Mr. Lamplugh maintains, probably strengthen this conclusion. Thus, in my paper on the Potton and Wicken phosphatic deposits, I called attention to the extraordinary abundance of rolled casts of *Ammonites biplex*, which I regarded as having been washed out of the Kimeridge Clay.

Mr. Lamplugh assures me that, at any rate, the majority of the ammonites in question are not *A. biplex*, Sow., but a form of *Olcostephanus*, characteristic of the missing beds, and unknown in the Kimeridge Clay. This I am quite prepared to accept, and in support of it I may mention that the casts of this ammonite are formed of phosphatic sandstone which would not be the case if they had been derived from the Kimeridge Clay as I supposed.

Everything points to the conclusion that the nodule beds represent long periods of time, and that they occur in areas of minimum sedimentation, or where sediment once formed has been subsequently removed by submarine erosion, probably not long after its accumulation.

But the Cretaceous phosphates do not always occur in the form of detached nodules or as nodular and more or less conglomeratic deposits. There are the remarkable phosphatic chalks of Taplow [(36)] and Lewes [(37)] described by Mr. Strahan, and the corresponding deposits of France which have engaged the attention of Messrs. Lasne,[(26)] de Mercey,[(27)] Cornet, Renard,[(8)] and Cayeux.[(7)] They consist of brown phosphatic grains, made up of more or less phosphatised foraminifera and prisms of *Inoceramus*, together with fragments of the bones, teeth, scales, and coprolites of small animals. The matrix is a fine calcareous powder largely composed of coccoliths, discoliths, and rhabdoliths. That the phosphatisation is not later than the deposit is proved by the fact that the matrix is calcareous.

The origin of the phosphatic matter has given rise to some discussion. M. de Mercey regards it as having come up from below, M. Lasne attributes it to the influx of rivers bringing down apatite in solution, Messrs. Renard, Cornet, and Strahan, suppose it to have been derived from the organisms of which such abundant traces occur in the deposit. In England I imagine we

shall all accept the last mentioned view, notwithstanding the fact, pointed out by M. Lasne, that the substance is a fluo-phosphate practically agreeing with apatite in composition.

CAINOZOIC PHOSPHATES.

The phosphatic deposits of Cainozoic age remain to be considered. They are the most important from a commercial point of view, for they include the enormous deposits of South Carolina, Florida, Algeria, and Tunis. In this country they are feebly represented by the interesting conglomeratic bed at the base of the Crag, particulars of which together with full references to the extensive literature will be found in Mr. Reid's *Geological Survey Memoir* on the Pliocene.[31] The curious box-stones containing a Pliocene fauna somewhat older than the Crag deserve more than a passing notice. They are nodules of brown phosphatic sandstone, which usually contain hollow moulds of *Pectunculus* or other calcareous shells.

The origin of nodules of this kind has been satisfactorily explained by Dr. Herman Credner.[9] In Suffolk they are evidently *remanié*, but in the Oligocene of Saxony precisely similar nodules occur in place. There the phosphatic matter, mainly phosphate of lime, has been concentrated round calcareous shells and fish remains; but the shells have entirely disappeared as in the box-stones of the Crag, and the fish are represented only by the denser and more insoluble portions of their skeletons and by their teeth and scales. Most of the bones have disappeared. As Dr. Credner points out, carbonic acid and ammonia are formed in connection with the decomposition of animal matter. Phosphate of lime is soluble in water charged with carbonic acid, and still more so in water containing ammonium carbonate. A solution of ammonium phosphate is thus formed at the expense of the fish bones, and one of calcium carbonate at the expense of the shells. The shells and the fish embedded in the porous sand thus become surrounded by water highly charged, in the one case with calcium carbonate, in the other with ammonium phosphate. When these two solutions react there is a precipitation of calcium phosphate together with some carbonate, and in this way the loose sand becomes cemented into a hard nodule enclosing, in the one case, a hollow mould of a shell, and in the other case, the more insoluble portions of the fish. The forms of the nodules, their microscopic structure and chemical composition, are all in accordance with the theory, which has been still further strengthened by experiments proving the solubility of fish-bones in a solution of ammonium-carbonate, and the precipitation of calcium phosphate on the addition of a saturated solution of calcium bicarbonate.

In some such way the box-stones in the Crag must have been

formed in an early Pliocene deposit of which they are now the sole survivors. The chemical reactions to which Dr. Credner has called attention have doubtless played an important part in the formation of many other phosphatic concretions.

Phosphates occur in greater or less abundance in many Tertiary deposits, the most important being those of Algeria, Tunis, South Carolina, and Florida. The richest deposits of North Africa occur near the base of the Tertiary Series, associated with marls and limestones. They contain bones and teeth of fishes and reptiles, often of considerable size and in great abundance.[2] Apart from this they have a general resemblance to phosphatic chalks. The matrix in which the larger constituents are embedded is made up of brown phosphatic grains, grains of glauconite, a few of quartz, and a calcareous paste. The phosphate occurs as more or less spherical grains, reminding one, as regards form and size, of oolitic grains. I have not been able to recognise with certainty either foraminiferal casts or small coprolites in the specimens I have examined from Djebel Kouif (Algeria), but they have been described as occurring in the corresponding rocks from Tunis.[41] The calcareous paste is composed of minute idiomorphic rhombs of calcite.

These phosphatic limestones have been traced over wide areas in Tunis and Algeria. The individual beds vary in thickness from a few centimétres to three métres, and the richest contain over 60 per cent. of tricalcic phosphate.

The Tertiary phosphatic deposits of North America are of Pliocene—possibly in some cases of Pleistocene age. They are found at intervals all along the Atlantic coast from Virginia to the extremity of Florida, and it is interesting to note that phosphatic concretions are now forming in the sea off the same coast. The well-known deposit of South Carolina[30] consists of irregularly shaped nodules which are sometimes cemented together so as to form masses weighing a ton or more. Associated with the nodules are "many sharks' teeth and cetacean bones, as well as the remains of the mastodon, megatherium, elephant, deer, horse, cow, hog, musk-rat, and other land animals" The matrix may be either sand or clay. The deposit rests on sands or marls, the latter containing from 55 to 95 per cent. of calcium carbonate. It is covered by Quaternary sands, clays, or marls. Many of the nodules are phosphatised portions of the underlying marl containing Miocene fossils.[10] The bones of land animals are never found embedded in the phosphate. The nodules are often more or less rounded, and bored by marine organisms. They contain from 25 to 70 per cent. of calcium phosphate.

Apart from its exceptional richness, the South Carolina deposit reminds one very much of that at the base of our own Crag. The Florida deposits are of a somewhat different character. The "rock phosphates" are phosphatised portions of the underlying Eocene

and Miocene limestones. Sometimes the phosphatisation has taken place without serious disturbance of the beds, but more frequently the component materials lie in the utmost confusion. Irregularly shaped boulders of all sizes up to 10 ft. in diameter lie in a matrix of soft phosphate or of clay and sand. In addition to the "rock-phosphates" there are, according to Dr. Dall, also pebble phosphates of Pliocene age. The latter rest uncomformably on Eocene and Miocene rocks, and give therefore some clue to the age of the phosphatisation.

What was the nature of the phosphatising agent? The descriptions by Eldridge,[14] Wyatt,[15] and others do not mention any facts pointing to submarine action. It was in all probability, as Darton [11] supposes, due to guano-deposits and therefore a surface phenomenon.

We have now passed in review illustrations of the principal types of deposits. Calcium phosphate may be formed by the accumulation of animal remains, by the replacement of carbonic by phosphoric acid through the action of solutions arising from the leaching of guanos, or the decomposition of animal matter, by direct deposition from solutions of calcium phosphate and by chemical precipitation, due to the interaction of solutions containing ammonium phosphate and calcium bicarbonate.

Deposits containing both calcium phosphate and calcium carbonate, such as the phosphatic chalks, may be enriched by the action of water charged with carbonic acid, owing to the comparative insolubility of the former.

The formation of phosphatic deposits may take place on the surface of the land, or beneath the waters of the ocean. In the latter case they appear to be limited to continental borders where deposition is slight, and where current action is often well marked.

From the earliest time down to the present day the physical and chemical conditions under which phosphatic deposits have been formed have remained essentially the same.

My duties as your President are at an end. I thank you most heartily for the honour you conferred upon me in electing me to the post, and I assure you that I shall carry away the most pleasant recollections of my two years of office. I desire also to thank the Officers with whom it has been a pleasure to serve, and to whose enthusiasm and ability the continued prosperity of the Association is so largely due.

My successor needs no introduction. He is not only a distinguished geologist, but also an old and tried friend of the Association, and we are all delighted that he has consented to act as our President. I have now great pleasure, mingled with regret that my own term of office is over, in asking Mr. Whitaker, President of the Geological Society, to take the Chair.

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ORDINARY MEETING.

FRIDAY, FEBRUARY 2ND, 1900.

W. WHITAKER, B.A., F.R.S., President, in the Chair.

George F. Brown and R. W. Gray were elected Members of the Association.

There being no further business the meeting then terminated.

ORDINARY MEETING.

FRIDAY, MARCH 2ND, 1900.

W. WHITAKER, B.A., F.R.S., President, in the Chair.

George Gibbens was elected a member of the Association.

A paper was read by Mr. F. A. Bather, M.A., F.G.S., on "Wind-worn Pebbles in the British Isles."

ANNUAL GENERAL MEETING.

FEBRUARY 2ND, 1900.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

Messrs. F. Trickett and J. Sheer were appointed scrutineers of the ballot.

The following Report of the Council for the year 1899 was then read:

THE numerical strength of the Association on December 31st, 1899, was as follows:

Honorary Members	14
Ordinary Members:	
a. Life Members (Compounded)	157
b. Old Country Members (5s. Annual Subscription)	6
c. Other Members (10s. Annual Subscription) .	390
Total	567

This shows a net increase of twenty-two as compared with the corresponding figures for the previous year.

During the year fifty-seven new members were elected. The Council regrets that the Association has lost two Honorary and seven Ordinary Members by death—Dr. Henry Hicks, Sir William Henry Flower, Charles Brongniart, George Dowker, John Dovaston, Henry Ullyett, C. N. Peal, James R. Gregory, and N. E. McIntire.

The loss of Dr. Henry Hicks will be deplored, not only by members of the Association, but by geologists in general. A native of St. David's, Pembrokeshire, he early devoted his energies to unravelling the geological structure of that district, afterwards extending his researches to other parts of the country. His labours have thrown considerable light on the relations of the older Palæozoic and pre-Cambrian rocks, as well as the Glacial and other Drift deposits. He was your President from 1883 to 1885, and always evinced a keen interest in the welfare of the Association. Your PROCEEDINGS contain many valuable papers from his pen, and his great experience as a field geologist was always readily placed at the disposal of the Association.

Sir William Henry Flower had been an Honorary Member of the Association since 1880. He will live in your memories chiefly on account of the admirable way in which he organised the re-arrangement of the collections at the Natural History Museum, South Kensington, of which he held the directorship until less than a year before his death, when he was constrained to relinquish the post on account of failing health.

GEOLOGISTS' ASSOCIATION.

Dr. Income and Expenditure for the Year ending Dec. 31st, 1899. Cr.

Dr.	£	s.	d.
To Balance from 1898	33	6	7
,, Life Compositions	30	0	0
,, Admission Fees	24	0	0
,, Annual Subscriptions	180	5	0
,, Dividends on Nottingham Corporation Stock ...	23	16	2
,, Sale of Publications	23	10	2
,, Sale of "Record"	2	18	6
,, Sale of "Paris Basin"	0	19	8
,, Advertisements*	5	0	0
,, Balance in hand of the "London Amateur Scientific Society," presented by the Council of that Society on its dissolution	1	4	0
	£325	0	1

Cr.	£	s.	d.
By Printing "Proceedings"	136	0	8
,, ,, Monthly Circulars	23	6	9
,, Miscellaneous Printing	6	10	6
,, Illustrating "Proceedings" and Circulars ...	11	11	0
,, Postages	39	16	4
,, Addressing	6	12	0
,, Library (including Honorarium to Librarian of St. Martin's Library)	12	11	5
,, Attendance, Lighting, Lantern, etc., at Evening Meetings	15	19	0
,, Excursions	2	18	11½
,, Insurance	2	16	0
,, Stationery	5	8	10¼
,, Miscellaneous Expenses	2	12	0
,, Balance in hand, Dec. 31st, 1899	58	16	7
	£325	0	1

* Due from Advertisement Contractor, Dec. 31st, 1899, £16 16s. 6d.

N.B.—A sum of £125 was paid on Sept. 29th to the Trustees by the Commercial Union Assurance Company on account of the damage done to the Association's stock of Publications by the fire at the Printers, and was expended by them on Oct. 5th in the purchase (including Brokerage, etc.) of £116 7s. 4d. Nottingham Corporation Three per cent Stock at 107¼.

We have compared the above account with the vouchers, and find it correct.
We have also verified the investment of £937 4s. 2d. Nottingham Corporation Stock.

R. HOLLAND, JNO. E. PIPER, } *Auditors.*

January 9th, 1900.

Charles Brongniart was elected a Member of the Association in 1879, and an Honorary Member in 1896. He was one of the few palæontologists who have devoted themselves to the study of the fossil insects, and will long be remembered for his masterly researches on the Palæozoic forms of that group.

In George Dowker the Association has lost an old and tried Member. He joined the Association at its foundation in 1858, and since then has at various times given valuable help in the conduct of excursions. So lately as Easter, 1897, he conducted an excursion to Romney Marsh, and contributed a paper to your PROCEEDINGS on the Physical History of that district. Only a few days before his death he read a paper on "Coast Erosion" before the Geological Section of the British Association at Dover.

John Dovaston was an accomplished naturalist and antiquary. He was a direct descendant of John Dovaston, the well-known antiquary of the eighteenth century. He will be remembered by many members who have been in the habit of attending the long excursions, and who will retain pleasing recollections of his kind and genial character.

The income of the Association for 1899 was £291 13s. 6d., the largest since 1887; and the expenditure was £266 3s. 6d., which included a sum of £21 16s. 2d. due to the printers for 1898. Thus, while the expenditure remains normal, the income has increased considerably, an increase due partly to the large number of new members who joined during the year, and partly to the unusually high receipts from the sales of Publications. Having regard to the very satisfactory financial position of the Association, your Council has thought fit to hand over to your Trustees for investment a sum of £50, representing approximately the composition fees received during 1898 and 1899. This investment was carried out in January of this year, and resulted in the purchase of £47 10s. Nottingham Corporation Three per Cent. Stock.

On June 8th, a fire occurred on the premises of the Association's printers, which, unfortunately, caused considerable damage to the stock of Publications stored there. Your Council particularly regret that the remaining stock of the "Record of Excursions" was destroyed.* As compensation for the loss incurred in the fire the Commercial Union Assurance Company paid to your Trustees a sum of £125, which has been invested by them in the purchase of £116 7s. 4d. Nottingham Corporation Three per Cent. Stock. The Association were also allowed to keep the salvage, and, so far as this has been fit for anything, it has been offered for sale at a considerably reduced price.

Five numbers of the PROCEEDINGS, containing 260 pages of

* It has since been discovered that a few undamaged copies of the "Record" remain in stock.

text, seven plates, and fifty-one other illustrations, have been published during the year 1899. The thanks of the Association are due to the authors for their contributions, especially to Dr. Barrois for "A Sketch of the Geology of Central Brittany," published in the July number; to Mr. H. H. Arnold-Bemrose for "A Sketch of the Geology of the Lower Carboniferous Rocks of Derbyshire," and for the excellent plates which illustrate the August number; to Dr. Barrois, The Société Géologique de France, The Société Géologique du Nord, and to the Geological Society of London, for clichés and the loan of blocks used in illustrating the PROCEEDINGS.

During the forty years' successful career of the Association, many papers read at the meetings, especially in the earlier years, were not published in the PROCEEDINGS, but several of them were printed separately. Hitherto no collection of these has been made for the Library. Fortunately, just before the fire above alluded to, a collection of these papers was made, and it was found possible to make two very nearly complete sets. They have been bound, and one set has been placed in St. Martin's Library, and the other, with a set of the PROCEEDINGS, is retained at University College.

A sum of £1 4s. was received from the late Amateur Scientific Society, to be expended on the purchase of books for the Library. This amount has been devoted towards the purchase of Sir A. Geikie's "Ancient Volcanoes of Great Britain." Amongst other additions to the Library may be mentioned the "Life of Sir J. Prestwich." The binding of the serials has been continued.

The number of volumes borrowed by members has not been very great, but considerable use of the books is made at the Library, both by members and others, and this use is facilitated by the card catalogue, which has recently been completed.

The following is a list of the papers read at the evening meetings:

"The Natural History of Cordierite and its Associates," being the address of the President, J. J. H. TEALL, M.A., F.R.S.

"A Sketch of the Geology of Central Brittany," by Dr. CHARLES BARROIS.

"The Drainage of Cuestas," by Prof. W. M. DAVIS.

"The Pleistocene Deposits of the Ilford and Wanstead District," by MARTIN A. C. HINTON.

"The Pleistocene Mollusca of Ilford," by A. S. KENNARD and B. B. WOODWARD, F.L.S., F.G.S.

"The Raised Beach and Rubble Drift at Aldrington, between Hove and Portslade-by-Sea, Sussex, with Notes on the Microzoa," by FREDERICK CHAPMAN, A.L.S., F.R.M.S.

"A Sketch of the Geology of the Lower Carboniferous Rocks of Derbyshire," by H. H. ARNOLD-BEMROSE, M.A., F.G.S.

"The Zones of the White Chalk of the English Coast. I. Kent and Sussex," by Dr. A. W. ROWE, F.G.S.

Lectures were delivered by H. W. MONCKTON, F.L.S., F.G.S., on "The Glaciers and Fjords of the Bergen District, Norway"; and by G. W. LAMPLUGH, F.G.S., on "The Geology of the Isle of Man."

Your thanks are due to all these gentlemen.

A Conversazione was held in November, and a full list of the exhibits will be published in the PROCEEDINGS.* Your thanks are due to the many members who contributed to the success of that evening.

The following museums were visited in 1899:

March 11th.—Mr. Hudleston's Museum, 8, Stanhope Gardens, under the direction of Prof. BLAKE, in the unavoidable absence of Mr. Hudleston.

September 11th.—The Prehistoric Department of the British Museum, Bloomsbury, under the direction of Mr. C. H. READ.

September 11th.—The Museum of Practical Geology, 28, Jermyn Street, under the direction of Sir ARCHIBALD GEIKIE, Mr. TEALL (President of the Association), and Mr. F. W. RUDLER.

September 11th.—The Geological Galleries of the Natural History Museum, Cromwell Road, under the direction of Dr. WOODWARD and Mr. A. SMITH WOODWARD.

September 11th.—On this date the President and Secretary and several members of the Société Belge de Géologie were of the party, and in the evening were entertained by the Presidents of the Geological Society and the Geologists' Association at the rooms of the Geological Society, Burlington House.

The following is a list of excursions made during the past year. Detailed reports will be found in Parts 3 and 5 of the PROCEEDINGS, Vol. XVI.

DATE.	PLACE.	DIRECTORS.
March 31 to April 4 (Easter)	Seaton, Sidmouth, Budleigh Salterton, and Exeter.	Horace B. Woodward, F.R.S., and W. A. E. Ussher, F.G.S.
April 8 (Cycling)	Winchfield to Wokingham.	H. W. Monckton, F.L.S., F.G.S.
April 15	Walton-on-the-Hill.	W. Whitaker, B.A., F.R.S., Pres. G.S., and W. P. D. Stebbing, F.G.S.
April 22	Staines.	W. Whitaker, B.A.
April 29	Weldon, Dene, and Gretton.	Beeby Thompson, F.C.S.
May 6	Thame District.	A. M. Davies, B.Sc., F.G.S.
May 13	Ilford.	T. V. Holmes, F.G.S.
May 18 to 24 (Whitsuntide)	Brittany.	Charles Barrois, D.Sc., and P. Lebesconte.
May 27 (Cycling)	Bushey to Harrow.	Rev. Prof. J. F. Blake, M.A.
June 3	Reigate.	Miss M. C. Crosfield, and Rev. Ashington Bullen, F.G.S.

* Vol. XVI, p. 286.

DATE.	PLACE.	DIRECTORS.
June 10	Rickmansworth and Harefield.	W. Whitaker, B.A., and John Hopkinson, F.G.S.
June 17	Lichfield and Cannock.	Prof. C. Lapworth, LL.D., and Prof. W. W. Watts, M.A.
June 24	Brighton and Rottingdean.	C. Davies Sherborn, and Henry Edmonds, B.Sc.
July 1	Cuxton and Burham.	G. E. Dibley, F.G.S.
July 8 (Cycling)	Chiltern Hills	H. J. Osborne White, F.G.S.
July 15	Guildford and Godalming.	A. K. Coomara-Swamy, F.G.S.
July 22	Claygate, Chessington, and Oxshott.	W. P. D. Stebbing, F.G.S.
August 2 to 9 (Long Excursion).	Derbyshire.	H. Arnold-Bemrose, M.A., Wheelton Hind, M.D., and J. Barnes, F.G.S.
August 10	Nottingham.	G. E. Coke, F.G.S., and Prof. Carr, M.A.
September 9	Charlton, Erith, and Crayford.	W. Whitaker, B.A.

Notwithstanding the exceptionally large number of excursions the average attendance has been very good.

Your thanks are due to the Directors of the excursions, and also to the following for assistance and hospitality:

Mr. and Mrs. Hudleston, at Stanhope Gardens; Mr. Gilbert, Mr. M. B. Duff, Mr. J. A. Sparks, and Mr. F. Gardner, at Staines; Monsieur T. Bezier, Monsieur A. Michel Levy, and Monsieur S. P. Oehlert, in Brittany; Mr. Anthony Alsop, Mr. Henry Fisher, and Mr. Wm. Hurst, in Derbyshire; and Miss Crosfield, at Reigate.

Your thanks are due to Sir Archibald Geikie, Director-General of the Geological Survey, for the presentation of the following sheets of the Geological Map of England and Wales: One inch, Nos. 13, 22, 71 N.E., 72 N.E., and 81 N.W., and for the loan of blocks from his "Ancient Volcanoes of Great Britain," and also to Dr. Barrois for Sheets 59, 74, 75, and 89, of the Geological Map of Brittany.

The management and arrangement of the excursions of the Association during the past year have been in the hands of the following committee: F. Meeson (chairman), Miss Foley, H. A. Hinton, Bedford McNeill, A. E. Salter, W. P. D. Stebbing, and A. C. Young. Your thanks are due to the members of this Committee for the trouble they have taken in arranging and carrying out a very full excursion programme.

Mr. Frederick Meeson having signified his desire to retire from the office of Excursion Secretary, the Council, on October 6th, accepted his resignation, and, acting under Rule XIV., appointed Mr. Bedford McNeill to fill the vacant office. Your thanks are due to Mr. Meeson for the able manner in which he has organised the excursions during the past year. The Committee appointed to prepare an excursion programme for 1900

was constituted as follows: Bedford McNeill (chairman), Miss Foley, Miss Whitley, H. A. Hinton, Frederick Meeson, H. W. Monckton, A. E. Salter, W. P. D. Stebbing, and A. C. Young, and it is recommended that the appointment of this Committee be confirmed as soon as the new Council meets.

Your thanks are due to the Council of University College for the facilities they continue to offer you in the use of rooms for your meetings.

As will be seen from the ballot papers now in your hands, there are several changes in the House List. Mr. J. J. H. TEALL, having filled the Presidential chair for the past two years, now retires from that office. You are indebted to him for an admirable account of the Natural History of so difficult a group of minerals as Cordierite and its Associates. During his term of office he has bestowed great care on the interests and welfare of the Association, and those who have had the pleasure of being associated with him on the Council readily acknowledge the debt of gratitude that is due to your retiring President.

Your thanks are also due to Mr. George Potter, who now retires from the Vice-Presidency, and from the Council; and to the following members of the Council who retire on this occasion: Mr. H. W. Burrows, Mr. T. V. Holmes, and Mr. J. Hopkinson.

Your Council have much pleasure in proposing Dr. Charles Barrois and Prof. W. M. Davis for election as Honorary Members. Dr. Barrois' numerous memoirs on all branches of geology have earned for him a well-merited distinction. On more than one occasion he has rendered signal service to the Association in the conduct of excursions. Prof. Davis is also well known by his many papers on the physical aspects of geology, and has recently contributed to your PROCEEDINGS a valuable paper on "The Drainage of Cuestas." The present wide-spread interest in questions relating to the forms of the earth's surface is largely due to his writings, and to his influence as a Professor.

The names of those suggested by your Council to fill the vacant offices will be found on the ballot paper.

On the motion of the Rev. Prof. J. F. Blake, seconded by Mr. J. D. Hardy, the Report was adopted as the Annual Report of the Association.

The scrutineers reported that the following were duly elected as Officers and Council for the ensuing year:

PRESIDENT:

W. Whitaker, B.A.Lond., F.R.S., F.G.S.

VICE-PRESIDENTS:

H. W. Monckton, F.L.S., F.G.S. | C. Davies Sherborn, F.G.S., F.Z.S.
E. T. Newton, F.R.S., F.G.S. | J. J. H. Teall, M.A., F.R.S., F.G.S.

TREASURER:

R. S. Herries, M.A., F.G.S.

SECRETARIES:

Percy Emary, F.G.S. | Bedford McNeill, A.R.S.M., F.G.S.

EDITOR:

H. A. Allen, F.G.S.

LIBRARIAN:

Wheatley J. Atkinson, F.G.S.

TWELVE OTHER MEMBERS OF COUNCIL:

L. L. Belinfante, M.Sc., B. ès L.
Geo. C. Crick, A.R.S.M., F.G.S.
Henry Fleck, F.G.S.
Miss Mary C. Foley, B.Sc.
R. Holland.
Dr. Edward Johnson.
A. S. Kennard.
Frederick Meeson.
A. E. Salter, B.Sc., F.G.S.
W. P. D. Stebbing, F.G.S.
Miss E. Whitley, B.Sc.
A. C. Young, F.C.S.

The best thanks of the Association were then voted to the Officers and Members of Council retiring from office, to the Auditors, and to the Scrutineers.

The President then delivered the annual address, entitled, "The Natural History of Phosphatic Deposits."

On the motion of Mr. H. B. Woodward, seconded by Mr. Upfield Green, it was unanimously resolved that the President's address be printed in full.

ORDINARY MEETING.

FRIDAY, APRIL 6TH, 1900.

W. WHITAKER, B.A., F.R.S., President, in the Chair.

George Scoular was elected a member of the Association.

A paper was read by Mr. G. E. Dibley, F.G.S., on "Zonal Features of the Kentish Chalk-pits between London and the Medway Valley."

WIND-WORN PEBBLES IN THE BRITISH ISLES.

By F. A. BATHER, M.A., F.G.S., of the British Museum (Natural History).

PLATE XI.

(Read March 2nd, 1900.)

IN the year 1868, Mr. R. D. Darbishire, of Manchester, received from his friend, Mr. Naylor, a curiously shaped pebble (Pl. XI, Figs. 6*a*, 6*b*). This had been picked up by Mr. Naylor as it was thrown out from the foundations of a house, then being built by Mr Bellhouse, and now known as Groby Lodge, at the corner of Groby Road and Racefield Road, near St. Margaret's Church, Bowdon, a suburb of Altrincham, Cheshire. Details of the excavation are wanting, but reference to the Geological Survey Maps of quarter-sheet 80 N.E. (scale 1-inch to the mile) shows that the underlying solid rock is believed to be the Keuper Red Marl, but that it is covered here by a series of Drift beds marked as Glacial Sand or Gravel. The writing on the stone indicates that the foundation was actually in gravel. Other constituents of the gravel at this locality are not forthcoming at present, so that for any further evidence we must turn to the pebble itself.

The substance of the pebble is a hard, heavy, liver-coloured quartzite. Apart from its peculiar shape, it is just such a stone as those forming the bulk of the Bunter Pebble Beds; and since those beds crop out within seven miles to the north-east and six miles to the west, there seems no reason to doubt that the Bowdon pebble was once a part of them From what presumably Cambrian rock these quartzite pebbles were originally ground down is still matter of dispute among students of Triassic geology. But this question, and even the question of its Bunter origin concern us little, since, as will be seen, the characters that give the pebble its main interest are such as must have been imparted to it after its removal from Triassic strata.

When the pebble is laid on a flat surface in its most stable position, we may distinguish an upper and a lower half. As seen either from above (Pl. XI, Fig. 6*a*) or from below (Fig. 6*b*), the periphery is roughly four-sided with rounded angles, and the diameters of the subquadrangular figure are respectively 58·5 mm. and 63·5 mm. The extreme height, when the stone is in the same position, is 39 mm. The cubic contents are 84·95 cc., the weight, 224·08 grams, and the specific gravity, 2·64. There is a marked difference of form between the upper and lower halves. The lower (Fig. 6*b*) is smoothly rounded just as one might expect a roughly cubical fragment of sandstone to become under the action of water and friction against other pebbles. The upper

half (Fig. 6*a*) forms a slightly irregular pyramid, with, however, three, not four, facets. The relation of these facets to each other and to the periphery is shown in Diagram 1, from which it appears that the pyramid is symmetrical neither in itself nor in its relation to the quadrangle. The facets are not plane surfaces; facet 2 is markedly convex, facet 3 is concave, and facet 1 is concave towards *a*, but almost flat towards *b*. The angles between the facets are slightly rounded, and this fact, combined with the inequalities of the facets themselves, renders measurement of the angles and slopes a difficult task. The approximate measurements are: ridge *a* = 127 deg., *b* = 127 deg., *c* = 120 deg. The slope of the facets to the horizontal plane, the assumed surface of the original substratum, is measured along a line bisecting the angle formed by the containing sides; this may perhaps be regarded as the angle of incidence of the facetting force. These slopes are approximately: 1 = 24 deg., 2 = 45 deg., 3 = 30 deg. Facet 2 appears from its size, its slope, and its convexity, to be the least removed from its original water-worn shape. Facet 1 appears, from its greater slope, and from the position of the apex, to be the most worn, although the including angle contained by the ridges *a*, *b* is the smallest.

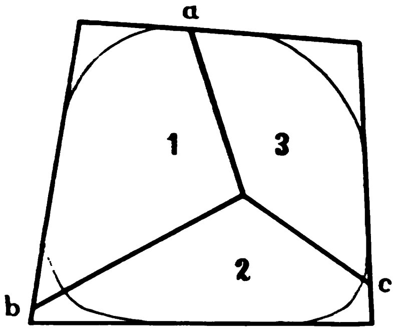

DIAGRAM 1.—OUTLINE OF THE BOWDON PEBBLE, AS VIEWED FROM ABOVE, SHOWING THE RIDGES, *a*, *b*, *c*, AND THE FACETS, 1, 2, 3. The outer rectilineal figure suggests the approximate outline of the stone before it was worn by water or wind. $\times \frac{2}{3}$ diam

Besides these obvious differences between the two halves of the pebble, there are differences in the nature of the surface. Not merely are the facets slightly rounded, but their surfaces are irregularly pitted as well as very slightly grooved, and differentiated according to the varying hardness of the stone. This is chiefly noticeable on the two larger facets, 1 and 3, and the groovings are at right angles to the dividing ridge *a*. Facet 3 has three broad grooves. Despite these irregularities, the surface,

DIAGRAM 2.—THE BOWDON PEBBLE, VIEWED FACING THE RIDGE *a*. $\times \frac{2}{3}$ diam.

especially of facets 1 and 3, is slightly polished. The under-surface appears rougher, owing to minute pitting, but it does not show any coarser grooving; except for an occasional obvious dent or crack, it is all equably rounded. It further differs in the presence of a slight yellow colouring. The distinctive surface-characters of the under-side pass on to the upper surface, and merge with those of the facets.

The remarkable features of this stone led Mr. Darbishire, after thirty years, to send it to the Geological Department of the British Museum, where, through the kindness of Dr. Henry Woodward, it was placed in my hands for study. Since, during an excursion of the International Geological Congress through Esthland in 1897, my attention had been directed to pebbles of similar shape, I had no difficulty in recognising the true nature of Mr. Darbishire's specimen. Pebbles of this form are, in fact, found in many parts of the world, and have long been known to geologists under the names of "Dreikanter," pyramid-pebbles, or facetted pebbles. Any theory of their origin must be applicable to all cases, while the true explanation of any one will probably be found to explain all.

The theory that ascribes the facetting, striation, and polishing of these stones to the action of blown sand is now so generally accepted that further labouring of the point might seem unnecessary. But the present paper is due to the following considerations. The explanation thus baldly given suggests many questions, some of which are not even nowadays readily to be answered. There is a danger lest this theory be strained, as others have been, to explain cases to which it is inapplicable. Very similar results may be produced by other causes; one must learn how to distinguish. The subject seems to have been overlooked by the majority of British geologists; but if this paper should serve as a guide to its possibilities and to the scattered foreign literature, further light may be thrown by the study on the past history of these islands.

Let us consider, first, the other agencies by which the surface of broken rock-fragments or water-rolled pebbles may be worn. Many of these have actually been adduced to explain the pebbles in question.

Human agency naturally suggests itself to one familiar with neolithic implements, and R. Virchow, describing pebbles of this kind, believed that they had been used for polishing (1870*a*)* or were preparatory to a finished stone weapon of primitive nature (1870*b*); but in 1871, having found similar pebbles in gravel beds, he discarded his previous views in favour of a glacial origin. In 1874 similar stones were still ascribed to human agency by Reil and Geiseler, but in the discussion their natural origin was advocated by Ascherson and Virchow. Geinitz, in 1886, related how

* For References see p. 416

facetted pebbles from Pomerania and Rügen were still labelled "Mahlsteine" in the Stralsund Museum. Even to this very year a large quartzite pebble with four facets, from Uelzen in Hanover, was preserved in the Ethnographical Department (Pitt-Rivers Collection) of the Oxford University Museum. My friend, Mr. H. Balfour, who was so kind as to send me the specimen for examination, wrote: "It is presumed it might have been a 'rubbing stone' for grinding or other triturative use, and I have retained it amongst the human tools." Now, however, he tells me that the specimen is to be placed in "a special series for natural products which simulate human workmanship, and may (seemingly do) take in the collector of human artefacts." No undoubted tool or weapon having the peculiar shape of these facetted pebbles has ever been produced, and they are often found in situations where a human origin is out of the question.

Other animals are not known to shape stones in this manner, but it is to be noted that sheep, cattle, and the like often rub stones to a high polish, while in South Africa rough masses of igneous rock are smoothed, polished, and marked with coarse parallel striæ by the rhinoceros. Specimens have been presented to the British Museum by Mr. David Draper.

The waving of grass against a stone often produces considerable polish, especially when the grass contains much silica.

Stones polished and facetted by glaciers generally differ from those worn by blown sand in one or more of the following points: the ground surface is flatter; they show characteristic glacial striæ—long, straight, and gradually tapering; the harder and softer components of the rock have not been differentiated. Nevertheless the glacial origin of many pebbles now believed to be wind-worn has been warmly advocated (Theile, 1885-86; Keilhack, 1884); Emerson (1898) still assigns the Dreikanter, at least in Old Hampshire County, Mass., to glacial agency; but although such pebbles have been found on the surface of terminal moraines, and even of the glacier itself, still the actual formation of the characteristic shape by a glacier has never yet been adduced. Indeed, it is not easy to see how the three regular facets of such a stone as our Bowdon pebble could be produced by glacial action.

The same remarks apply in the main to C. von Gutbier's view (1858) that the stones were fixed in floating ice and ground against a rocky floor, with the additional difficulty that, if the stone were loosened sufficiently for it to be turned round for the grinding of a fresh facet, it must have fallen to the bottom. It is not denied that stones are ground by this agency. Among facetted stones usually ascribed to ice action are the well-known pebbles of the Punjab. After reading the literature bearing on these,* and minutely examining the specimen described by Dr.

* Blanford, 1886; Noetling, 1896; Oldham, 1887; Stone, 1889; Warth, 1888; Wynne, 1886.

W. T. Blanford (Nov., 1886), I agree with most of the writers on the subject that, whatever be the agency that shaped these stones, it was not blown sand.

The action of water, or of water and sand, has been known to grind stones in a manner other than the normal rounding. Professor Boyd Dawkins tells me of an instance on the coast of Cornwall. There he observed a number of stones ground on one side to a sharp edge, so that he took them for implements, until he saw that they had originally projected from a bed of clay, over which the tides swept sand backwards and forwards in such a way as to grind the exposed portions. In the discussion on Virchow's paper (1871), Braun supposed that the shape of the typical pyramid-pebbles was produced by one stone rubbing against another when disturbed by running water. This idea was elaborated in the "Packungstheorie" of G. Berendt (1885), who imagined that, as water passed through a bed of shingle or gravel, the pebbles were rubbed one against another, and so tended to assume a pyramidal shape as the most economical of space. This theory proves too much, for had such been the *modus operandi*, the stones would have been facetted both above and below, whereas such "Doppel-dreikanter" are extremely rare. The explanation is further inapplicable to those numerous facetted pebbles that occur where the presence of water is out of the question. It is, however, possible that the action described by Berendt does have some effect. F. E. Geinitz (1887) believes that facetted pebbles are thus produced in the beach at Heilige Damm, in North Germany, and he quotes Commenda (1884) who, in giant's cauldrons at Steyregg, Austria, discovered "Dreikanter of a hard garnetiferous greenstone" along with "round, yellow gravel," the whole covered by Danube alluvium. These particular pot-holes are ascribed to the melting of glaciers.

In the pebbles of the Bunter Beds* there are often found concavities, which Mr. Mellard Reade ascribes to the grinding of one stone upon another, assisted by water and perhaps sand. Others, noting the transversely fractured pebbles of these beds, as well as the frequent occurrence of cracks radiating from these depressions, have regarded pressure due to earth-movement as the cause of both phenomena. In the Lower Old Red Sandstone conglomerate of the Cushendun caves, Antrim, Mr. Upfield Green has collected a rounded quartzite pebble with one side striated and polished. This resembles the glaze produced by blown sand; but, since the stone has been crushed and cracked by pressure, and since the striæ are all parallel to its long axis, I believe the polish to be the effect of slickensides. Allusion may here be made to soil-cap movement, which striates and grinds underlying rocks. Typical Dreikanter rarely occur in situations where any

* See Ramsay, 1855.

of these explanations are at all admissible. It is, however, the case that those of the German Drift are often marked, on the facets and elsewhere, by round hollows, up to 2 cm. in diameter, and of varying depth. These were ascribed by Gutbier (1858) to the driving of one stone into another under ice-pressure, in which case, as in that of the Bunter pebbles, one would expect to find the stones more crushed and cracked. The slight grooves, sometimes as much as 10 cm. long, which occasionally run up to these hollows, do not appear to represent cracks. Wittich (1899) who supposes the excavating agent to be blown sand, suggests that some of the holes may be due to the former presence of clay galls or calcareous fossils. Some of the smaller depressions or pittings may be due to the alternation of extremes of temperature, since this is known to flake portions off stones, especially in desert regions. To this cause may possibly be due the pittings on the under surface of the Uelzen pebble in the Pitt-Rivers collection.

In the case of composite rocks, such as the coarser crystalline igneous rocks, the difference in co-efficient of expansion of the constituents renders the stone easily attacked by variation of temperature. This factor in desert regions and the freezing of water in the joints under a moister climate, cause the breaking up of rocks into angular fragments. Thus Rothpletz, Johnstrup (1874), Shaler (1889), and Keilhack (1884) have attempted to explain at all events the main contours of the facetted pebbles; but we have yet to learn of a rock in which the joint-planes lie at the angles usual in pebbles facetted by blown sand.

Some of the appearances characteristic of undoubtedly wind-worn pebbles may be closely simulated by the solvent action of water, with or without acids. The glazed surface closely resembles the so-called "fresh-water patina," and among similarly polished stones may be mentioned the bones and teeth found in the English Red Crag, and the small pebbles of chalcedony, quartz, and flint in the Red Chalk of Hunstanton. Geinitz (1886) has even denied that the facets of Dreikanter are distinguished by extra polish; but in this opinion he is singular. Writing of certain pebbles found in the drift of Nantucket, Shaler (1889) says they "may be compared to crystals of rock-candy partially dissolved away. The surface of the boulders becomes very smooth, though uneven; in some cases pebbles or crystals contained in it are left as rounded projections on its face." This effect is most conspicuous in siliceous pebbles, and in no case is it observed so much as 10 ft. below the surface of the soil. Shaler ascribes it to the action of surface waters containing carbon dioxide, and he carefully distinguishes it from the erosive action of blown sand, which is said to be inconsiderable there. None the less the description is precisely applicable to certain wind-worn stones; and it must be remembered that certain facetted pebbles from

the same beds, ascribed by Shaler to joint-fracture and ice-polish, are now explained as wind-worn (Davis, 1894).

As for polish, Baltzer (1896) says that "Gletscherkanter," worn down under the glacier in ground moraines by the finest loamy sand, show the varnish polish just like wind-worn stones.

We may now consider undoubted instances of the action of blown sand, with special reference to facetted pebbles.

Not far from Wellington, New Zealand, is an isthmus, a little over a mile across, separating Evans' Bay on the N.W. from Lyall's Bay on the S.E. In the middle of this is a ridge of boulders and pebbles, and on each shore the sand is piled up in dunes. The isthmus is confined on the N.E. and S.W. by hills. When the north-westerly winds blow through the gap, which is only half a mile wide, they drive the sand over the boulder-bank with much force, and when the winds change to the south-east, the sand is driven back again. These happen to be the two prevalent winds, and in any case the area is protected by the hills from the action of other winds. As a result the stones of the boulder-bank are planed off on the two sides opposed to the winds. At first the top of the stone remains flat, but at last the two sides meet in a sharp edge.

Similar stones, fashioned under much the same conditions, are met with in other parts of New Zealand—*e.g.*, on Hokitika beach, on the west coast of South Island. One of these, figured on Plate XI (Fig. 5), shows, at the upper end of the figure, a small facet, apparently the remains of the flat top: thus there are three ridges. But it does not appear that any of the stones from New Zealand localities assume the markedly triquetrous form of our Bowdon specimen and of the German "Dreikanter"; and this may be the reason why the explanation of the former by Travers (1870) and Enys (1878) was not applied to the latter until Gottsche in 1883 drew attention to it.

In attempting to explain the triquetration, we must remember that, even where most conspicuous, it is by no means found on all the specimens. In fact, a pebble may present almost any number of facets, from one to at least eight. Even when the number is three or four, there is great variation in the relative sizes and outlines of the facets. It is, however, convenient to take the Dreikanter as the type, and of this form we find the most convincing elucidation by A. Mickwitz, of Reval (1885-87). South of that town is a lake, the Ober See, and its north-west shore ("nordöstlichen," Mickwitz, must be a *lapsus calami*) is covered by sand dunes. Where the Pernau Road and the Baltischport Railway approach the lake, the dunes merge into gravel banks and terraces, which stretch westward to a sandy plain north of the Blue Hills. The sand from one side or the other is constantly being blown over the gravel ridges, and all the surface constituents of the ridges, from fine gravel to massive

blocks, have their upper sides polished by the sand, while on the under side they differ in no way from ordinary drift gravel. Regularly facetted stones do not occur at the lower levels, but are abundant on the higher terraces, and their most conspicuous, though far from commonest, form is the Dreikanter. Between these and the simply polished stones there is every gradation. Both are alike in showing a differential wearing of the constituents of the rock, producing ridges, rugosities, and pittings. Now, if the facets of the Dreikanter are due, as in the case of the New Zealand pebbles, to the prevailing winds, one would expect to find them all oriented alike, although allowance might have to be made in each case for the deflection of the wind by local conditions. This is actually the case, as Mickwitz has proved by taking the bearings of a large number. Further, one would expect to find three prevailing winds, acting at right angles to the mean direction of the facets, viz., N., S. by 50 deg. W., and S. by 60 deg. E. This is believed by Mickwitz to be the case, but on this point his observations are not yet published. Moreover, the local conditions appear to have undergone recent change, since woods have grown up which shelter the Dreikanter terrace, and permit lichen to grow over the stones, especially on their southern sides. Some of the stones from this classical locality are figured on Plate XI, and show many of the characters to which allusion has been made.

For more complete correlation of facets with prevailing winds, we turn to the valuable paper by Baron G. de Geer, of Stockholm (1887). The stones described by him have, however, only two facets for the most part. They were found at Fjelkinge, on a field where rye had been grown two years before, and where a fresh surface had consequently been exposed by the plough. The mean direction of the ridge between the facets was N. by 22 deg. W., and the prevailing winds at the neighbouring meteorological station of Kristianstad were at right angles to this direction. Moreover, the field was sheltered from other winds by adjoining hills, so that the conditions were doubly favourable.

The foregoing instances are enough to show that blown sand is an effective cause of facetted pebbles, including Dreikanter. They are corroborated by the observations of Stone, on pebbles in Maine (1886) and Colorado (1889); of Wahnschaffe (1887), on pebbles at Gräningen, near Rathenow; of Dames (1887), on pebbles below the Regenstein in the Harz; of Walther (1887), in Egypt; of Verworn (1896), in the desert of Sinai; and of Andersson (1896), on Gotska Sandön, in the Baltic. We may now proceed to discuss the process in more detail.

It is often supposed that the wind in action strikes the stone in the direction of the ridge and is divided by it, so that a stream of sand passes to right and left, forming two facets. Those of the above-mentioned authors, however, who have attempted

correlation of the facets with the prevailing winds, agree that the wind acts at right angles to the ridge. This, as Wahnschaffe says, is further proved by the frequent hollowing of the facet. Groovings and striations of the facets also run in this direction, as may be seen in Fig. 5 of Plate XI. Heim (1888), while admitting this in the main, ascribes more importance to the original form of the stone than to the direction of the wind. Each facet, he says, corresponds to a truncated side of the original pebble, and a sharp notch on any side results in a groove on the facet; a wind blowing from any direction is diverted by the face of the pebble, and, whether from right or left, would have precisely the same action on that face. This might be the case if that particular face were the only part of the pebble exposed to the eroding agent. But, as Heim himself says, the ridges are produced where the side attacked by the wind meets the sides sheltered; and it is clear that when the wind is S.E., that portion of the pebble sheltered is not the same as when the wind is S.W. In other words a S.E. wind attacks not only the southern face, but also the eastern face, and wears down the S.E. ridge between them. The action of a S.W. wind is quite different. But anyway Heim's assertions are made without attempt at proof.

It is, of course, obvious that, at least in the earlier stages, the original form of the pebble must have some effect. The truncation of two corners of a four-sided pebble would make it six-sided, and so forth. A rounded pebble attacked by winds from the S.E. and S.W. alone would become a Dreikanter, with two flat or concave facets due to blown sand, and the third the original convex surface. It is probable that facet 2 in the Bowdon specimen is such a surface, and this would account for the less polish and pitting of it as compared with facets 1 and 3. The Reval specimens, represented in Figs. 2, 3, and 4 of Plate XI, do, on the contrary, appear to be wind-worn on all three facets; and the fact that, in each of these pebbles, the facets harmonise with the outline, may be due to something more than chance. Similarly the four facets of the Uelzen specimen (Pitt-Rivers coll.) coincide with the four sides of the stone, and are all wind-worn. In this case there is a median ridge parallel to the long axis of the pebble, and two ridges diverging from each end of it. Thus the facets are two large and two small, and this arrangement is characteristic of pebbles with four facets. In this case two of the ridges, diagonally opposed, are well marked; the other two are rounded. This suggests that the stone was subject to the action, not of four equally persistent winds, but of two main winds which occasionally veered into the adjoining quarter. Wittich's remark (1899) that long pebbles usually have but one ridge running lengthwise, is certainly borne out by the Hokitika specimens that I have seen. Some of these also show how stones

with vertical sides (not necessarily thick, *i.e.*, high, fragments, as Wittich says) are first smoothed on those sides, so that the stone retains a flat top, with edges parallel to the periphery of the stone. The relic of such a top is shown in Fig. 4 of Plate XI, and there is a trace of it in the pebble represented in Fig. 2. Wittich also notes that fragments of Bunter sandstone usually have a parallelepipedal form, and their wind-worn facets are consequently rectangular as a rule. The Reval specimen shown in Fig. 1 of Plate XI has but one definite facet, though the rest of the upper surface is polished. Another specimen collected at the same time is of similar size, shape, and polish; but whereas the facet of the figured specimen faced south, that of the other specimen was turned to N.N.W. These two pebbles, then, seem to have been affected by minor local conditions.

The number of facets on a stone may then be due partly to its original shape, partly to the number of prevailing winds acting on that particular stone. But the number may be increased by other aspects of the pebble being opposed to the winds. This may be brought about by a change in the surroundings deflecting the winds, or depriving the stone of some shelter it originally enjoyed; or, as is more usual, by some shifting in the position of the stone itself. Such shifting may be readily caused by the kick of a passing animal, and a recurrence of the accident might multiply the facets indefinitely. But the wind itself may alter the position of a stone, not, except in the case of smaller, loosely-strewn pebbles, by actually blowing the stone over, but by wearing away the ground on which it lies. This phenomenon is common on a sandy soil. The surrounding sand is first blown away, leaving the pebble as the cap of a small earth-pillar, which is at last eroded to such an extent that the pebble topples over, and presents another surface to the destructive agencies. In some such way may be explained the Doppel-dreikanter, which are occasionally found. The wearing of the stone on its under surface may, as Wittich (1899) points out, take place while it is still the top of an æolian table; the stone becomes pointed underneath. A similar mushroom form is seen in larger masses in the desert. But the more usual effect of undermining action is to prevent the formation of pyramid-pebbles entirely. The stones are rolled over so constantly that time is not allowed for the production of perceptible facets, but the whole stone acquires a fine polish. This is exemplified by the smaller pebbles of the Cairo desert, and was also seen in many of the New Zealand specimens exhibited by Mr. G. J. Binns when this paper was read. Undermining does not take place to an appreciable extent when the pebble rests on, or is imbedded in, a clayey substratum; but that this condition is necessary for the production of Dreikanter is disproved by many instances.

The observations of Walther (1887-91), chiefly made in the Galala Desert, between the Nile and the Red Sea, are of much importance. He denies that there is any causal connection between the number of facets and the size of the pebble, and has failed to discover any connection between the direction of the edges and that of the winds. This seems to upset the theories of Mickwitz, De Geer, and others; but, as Walther points out, the wind in the desert is very inconstant, and allowance must also be made for the frequent shifting of all the pebbles. Attention must therefore be directed chiefly to the environment of the individual pebbles. Facetted pebbles, he explains, always lie among other pebbles: the sand flows in streams along the ground, and these streams are divided by the larger pebbles and again unite; stones on which two such converging streams impinge acquire two facets (and ultimately three ridges, as explained above). Stone's observations (1889) at the base of the Rockies are in harmony with the above. The boulders present "polished facets in all positions with respect to both vertical and horizontal planes. A single boulder may have a dozen or more facets. . . . The grooves often have different directions on different faces; but in places where the wind can only act when blowing in a certain direction, they are parallel. They can often be traced up to a facet angle and around on to the next facet, especially when the angle is quite obtuse. Grooves can be found at all angles to facet edges, both parallel and transverse to them. The positions of the facets . . . are determined partly by the original shape of the stone, and partly by the accidents of the grinding process." "Several facets can be formed contemporaneously." Thus we see, not only how a single wind may produce two facets, but how all the variable breezes from half-way round the compass may be deflected into an unvarying channel. At the same time if this were a complete explanation of all Dreikanter in other situations, the observations of Mickwitz, De Geer, and Wittich, as to the correspondence in orientation of the facets, would be themselves inexplicable.

We note here a difference between the action of blown sand on bosses of live rock and on stones lying on sand or gravel. In the former case, as instanced by Stapf (1887) from the stone desert of the ! Khuiseb valley as well as along the Guadiana above Mérida and at Cáceres, the first results are "smooth, rounded humps, to be distinguished from glaciated humps only by their rougher surface, the absence of [glacial] striæ, and the want of a sharp lee side." But with loose stones, the ultimate form is neither this nor a plane surface, owing to the constant undermining. From this and preceding considerations it may be inferred that the connection between a facetted pebble and such persistent conditions as the winds of the locality will best be observed in the larger pebbles. Such facetted stones as those figured by

Theile (1885), 1·7 and 1·6 metres long, would not readily be displaced.

As introduction to the minuter and more specific characters of wind-worn stones, it will be well to consider the action of the sand-blast, whether natural or artificial. It is often assumed (as seemingly by Mickwitz) that the formation of marked facets must have been the work of centuries. De Geer's observations (1887) will already have caused us to doubt this, and they are confirmed by others. In other respects the natural action of blown sand is well known to be often severe. Long ago Graf von Baudissin (1865) related how, on the island of Sylt, the window-panes were cut through by dune sand. The same occurrence is recorded by Winchell (1886) from Cape Cod. Telegraph wires, says Wittich, are cut by sand on Russian steppes. Gilbert, in the discussion on Davis' paper (1894), said that fifteen miles east of Watertown, in northern New York, pebbles had been carved within a few years of the clearing of the surface. Among pebbles kindly collected for me by Mr. Mellard Reade from the sandy beach of Crosby, north of Liverpool, are pieces of bottle-glass with fresh, bright fractured edges, but with the exposed upper surface ground by the blown sand, and with striæ in groups at different angles. The action of the artificial sand-blast is remarkably rapid; by its use De Geer brought a freshly broken face of quartzite to the characteristic pitted and polished surface in fifteen minutes.

The effect of the sand-blast on rocks has been investigated by Tilighman (who is quoted by Woodworth, 1894) and especially by Thoulet (1887). I abstract so much of the latter's paper as is germane to the present issue. Abrasion varies directly as the quantity of sand. Polished rock resists abrasion better than unpolished, and fresh unworn sand abrades quicker than worn sand. The coarser the sand, the more rapid the action. Abrasion varies directly as the pressure of the wind. Abrasion is most intense when the surface is perpendicular to the sand-stream; it diminishes rapidly when the angle of incidence is below 60 deg. Fine-grained rocks, whether heterogeneous or homogeneous, resist abrasion better than coarse-grained. A rock is abraded more rapidly when moist than when dry, and the more so the more porous and absorbent it is. If Woodworth is correct in quoting Tilighman to the effect that the cutting is more rapid when the angle of incidence is 30 deg., and if Woodworth's other remarks on this point are based on Tilighman, then the observations of the latter are irreconcilable with those of Thoulet.

Applying Thoulet's conclusions to the operations of nature, we see that these must be more effective at first, and that a point would be reached when, owing to the polish of the pebble, the smoothness and fineness of the sand-grains, and the slope of the facets, scarcely any abrasion would be in progress. Pebbles which might originally have had very various forms, would

gradually approximate so far as the slope of their facets was concerned, and thus would arise that mechanical similarity of angle which has led some authors to compare it even with the results of crystallisation.

Thoulet's opinion as to the effects of moisture must surprise those who associate excessive wind action with an abnormally dry climate. This laboratory result is in fact little applicable to nature, for the rain that moistens the rocks also lays the sand and dust. Moreover, in humid regions, such traces of sand action as might from time to time arise are speedily obliterated by the more rapid wasting due to decomposition and solution (Gilbert, 1875). In this connection it may be remembered that dryness does not imply heat. Allusion has already been made to wind-worn pebbles on the surface of glaciers, and Chelius (1892) has recorded the blowing of sand and dust over snow near Darmstadt. As is well known, snow itself may replace sand as the corroding substance.

DIAGRAM 3.—A PEBBLE FROM REVAL (PL. XI, FIG. 2), VIEWED FROM THE SIDE TO SHOW ELEVATION, TRUNCATE APEX, AND TERRACING OF SIDES DUE TO DIFFERENTIATION OF CONSTITUENTS. $\times \frac{2}{3}$ diam.

The chemical composition and the texture of rocks have considerable influence on the form of facetted pebbles. In the Sahara, according to Rolland (1890), blown sand chiefly works on limestones. Walther says that in the Galala desert Dreikanter are formed only of Cretaceous limestone, having a fine, compact, uniform grain ; Eocene limestones are too soft ; nummulitic limestones too unequal ; the crystalline rocks quickly decompose. In more northern latitudes fine-grained quartzite seems to be the rock that receives the smoothest surface and the most symmetrical facets, the latter feature, however, depending rather on the original shape of the stones than on their texture. Milky quartz and flint are not so well carved. Composite igneous rocks have their constituents differentiated, as is well seen in the granite pebble from Reval (Pl. XI, Fig. 2, and Diagram 3). The same is the case with conglomerates and stratified rocks in which the laminæ are of unequal hardness. A slight grooving due to the latter cause is seen in the Uelzen specimen (Pitt-Rivers coll.). Wittich

describes wind-worn blocks of coarse conglomerate which are derived from the Upper Bunter Sandstone and are found in the drift of the Main, near Frankfort; in these each pebble stands out and has its own facets. The same is the case with the Khan-Khaisk conglomerate of Central Asia. A frequent result of this differential action is the production of a step-like or terraced appearance on the facets or other worn surface (Diagram 3), and it is noteworthy that the same appearance on a larger scale is often seen in the hill scenery of desert lands (see Rolland, 1890). So characteristic are the different shapes and surfaces that slight practice enables one to distinguish the composition of the pebbles from photographs alone with some confidence (see the plates of Davis, 1894; Berendt, 1885; and others). Obruchev (1895) has classed the rocks of the Central Asian deserts into eleven groups, according to their mode of wearing under blown sand.

The fluting of rock-surfaces by blown sand does not appear always to be due to the composition of the rock, but to the direct action of the blast. If the wind be exceptionally strong, with its force perhaps enhanced by concentration in a gully or cleft, as in the Pass of San Bernardino, California (Blake), the abrading force is so greatly increased that hard materials yield to it nearly as much as soft. In other words, differentiation is greater when the force is enough to attack soft, but not enough to attack hard, minerals. If now this fierce blast be broken up into streamlets by superficial irregularities, each streamlet will carve for itself a small runnel, which will proceed straight forward for an appreciable distance without regard for hard and soft. Thus one must explain the remarkably carved surface of the basalt boulder in Colorado, beautifully figured by Gilbert (1875, pl. viii). To such action also I am inclined to ascribe the appearance of the fluted granite surfaces at Mount Sorrel, Charnwood Forest, examples of which have been lent me through the kindness of Prof. W. W. Watts, who has recently drawn attention to them (1900).

Grooves due to direct wind action and not to rock texture are the subject of valuable speculations by Stone (1889). The facets of a small stone "nearly on the same level as the surface of the soil or of other stones around it" often have "a gently undulating surface, the crests of the low undulations more often being transverse to the direction of the wind and an inch or more apart." In this case "a large part of the carving is done by flying grains as they first strike the stone." In the case of bigger or loftier surfaces "a much larger proportion of the grinding is done after the blowing stones [grains] have once rebounded from the fixed stone." The grains, being mostly of irregular shape, bound from side to side, and thus form "shallow grooves parallel with the direction of the prevailing wind . . . an inch or less in breadth and seldom more than the sixteenth of an inch in depth." These "grooves can not

seldom be traced up and over a long transverse undulation, or they give rise to a large number of conchoidal depressions."

This branch of the subject cannot now be pursued further. Allusion may, however be made to the remarkable effects of wind described and figured by Rolland (1890). In the south of the Sahara certain plateaux are polished like a looking-glass, with striæ, grooves, etc. The flanks of certain hills—*e.g.*, Gour Ouargla (near El Goléa)—are engraved, sculped, bored, and reduced in places to a regular stone lacework, of which the pattern sometimes allows one to recognise the direction of the wind. Here, also, are pebbles of limestone and silica, with the surface covered by vermiculate grooves like arabesques.

The polish so often alluded to as a result of the sand-blast is, of course, confined to the harder rocks. Baltzer (1896) distinguishes "glänzende Politur" (bright polish), especially seen on compact and finely crystalline limestones, from "matte Politur" (dead polish), seen chiefly on sandstones and coarsely crystalline limestones. But every gradation is to be found. Nearly all writers compare this polish to a varnish; Stapf (1887) says, "a glaze-like polish"; Blake (1855) writes, "The polish is . . . as if the pebbles had been oiled and varnished." What is the difference between a glaze or varnish and a surface polished by rubbing? It appears to me to be essentially an optical effect due to the irregularity of the varnished surface, as contrasted with the regular smoothness of the rubbed surface. In the former case the rays of light are reflected at all angles and from various levels. This is just the character of the wind-worn surface; the polish lies equally on eminences and depressions, and minor irregularities are in fact increased rather than diminished by the sand-blast. A pebble that is wind-worn above and water-worn below, appears to the eye smooth above and rough below; but to a sensitive finger, or to the tongue, it is the under surface that appears smooth, while the shining upper surface is full of irregularities. A surface polished by glaciation or water-grinding feels smoother.

This "varnish" or "patina" of desert pebbles, which increases the blinding effect of the reflected sun, and which must assist the mirage in deluding the traveller with the vision of water, must not be confused with another characteristically desert patina. The "rocs vernissés noirs" of E. Reclus are indeed supposed by Rolland to be dark Devonian sandstones polished by sand. But, as he points out (1890, p. 216, footnote), there is also "a sort of black patina, formed, no doubt, under atmospheric and solar action. In the same way the white Cretaceous limestones of the Algerian Sahara are often covered by a yellow patina, *e.g.*, on the plateau of El Goléa." This kind of patina still needs explanation; some (*e.g.*, Obruchev, 1895) suppose it to be connected with the chemical composition of the rock, a sort of efflorescence of silica and iron; at any rate, it is no effect of blown sand.

The effects of wind and other desert conditions have a more than terrestrial interest; Goldschmidt (1894) has figured and described similar appearances on the surfaces of meteorites.

Facetted and wind-polished pebbles have been found over almost all parts of the present surface of the earth, under tropical, temperate, and Arctic climates, on plains, on hills, or in valleys, scattered over steppes and deserts, or confined to small clearings in the midst of fertile fields and evergreen forests. Here are a few recorded localities: Deserts of Libya and Arabia (Walther, 1887-91); Desert of Sinai (Verworn, 1896, Sarasin); Kalahari Desert of S.W. Africa (Stapf, 1887); 16 kilometres from Walfisch Bay, S. Africa (Captain T. Een, *fide* De Geer); Deserts of Central Asia (Richthofen, Obruchev, 1895); Reval (Mickwitz, 1885); Schleswig-Holstein (Gottsche, 1883; L. Meyn, 1872); Jutland (Johnstrup, 1874); Anholt in Kattegat (Torell, *fide* De Geer, 1887); Silfåkra, near Lund, East Scania, and N. of Fjelkinge, near Kristianstad (De Geer, 1884-87); Halland (Lundbohm, *fide* De Geer, 1887); Iceland (Keilhack, 1884); sandy plateau of Brenne, in France (Lapparent, 1899); surface of old moraines near Lyon, collected by Chantre (*fide* Torell, *apud* Berendt, 1889, and De Geer, 1887); New Zealand, various localities (Travers, 1870; Enys, 1878); California (Blake, 1855); Colorado (Stone, 1889); Nebraska, Bad Lands (Gilbert and others); Maine, especially near Bethel (Hitchcock, 1861; Stone, 1886); New Jersey (Salisbury, 1893); northern New York (Gilbert, 1894). Many of the facetted pebbles from Germany may likewise be of recent origin.

The geological occurrences of facetted pebbles are mostly in the Drift, and the pebbles received their present form in Post-glacial times. The localities in Germany are too numerous to be quoted here; they will be found recorded in the papers by Berendt (1885), Chelius (1891,-92,-94), Geinitz (1886,-87), Gutbier (1858,-65), Wittich (1899), and others. As the last-named author remarks, in Germany the Dreikanter were deposited where they now are in middle or old diluvial times: but they were facetted during the succeeding young diluvial epoch, the Loess period, or even the present day. The Loess itself is too fine to have abrasive power, and the wind which transported it did not, of course, transport pebbles along with it. Facetted pebbles are, however, frequent in the basement bed, or "Steinsohle," of the Loess, being always found in the topmost covering layer of the underlying Drift, whatever that may consist of, over the whole North German Plain (Sauer 1889). In Saxony, for instance, Herrmann (1880) and Weber (1890), tell us that facetted pebbles are rare in Loess-lehm, more numerous in the coarser sand and in the Steinsohle. A typical case is described by Wittich (1899), who found Dreikanter in their original position in drift gravel beneath blown sand, at 1 metre from the present surface, in a pit at the Town

Electric Works of Isenburg. The most polished side faced S.W., the other facets were N.E. and N.W. No evidence as to the present winds of that locality is given. The pebbles of Cape Cod have already been discussed (see Davis, 1894). So, too, Woodworth (1894) observed in Matakeset Creek, S. New England: "A continuous line of sculptured and polished pebbles lying at an average depth of from one to two feet beneath the surface," "overlaid by a deposit of fine wind-blown beach sand." The under surface of the pebbles, where in contact with the underlying gravels, was not facetted, and no facetted stones were found in the underlying gravel. Woodworth concludes that the facetted pebbles are "evidently glacial stream pebbles reshaped *in situ*." The conditions at the close of glaciation in any country must have been most favourable to the production of pyramid-pebbles. The land was bare and exposed to winds; its surface was strewn with boulders and pebbles, many of them already ground to an appropriate shape; and there was associated with them an abundance of angular sand, far better for the work than marine sand. These facts account for the association of pyramid pebbles with glacial deposits, an association so frequent as to have led Prof. B. K. Emerson (1898) to the rash assertion that they are "as characteristic of the till as graptolites of the Silurian." Nevertheless, as Gottsche (1883) has warned us, the pyramid pebbles of the Drift characterise no particular bed, and the period of their facetting extends from glacial times to the present day.

From formations of a remoter past, a few cases have been recorded of facetted pebbles, probably ascribed with justice to the action of blown sand. Thus L. Meyn (1876) claims to have found pyramidal pebbles *in situ* in kaolin-sand of Miocene age on the island of Sylt. Professor T. Rupert Jones (1878), among pebbles of "quartz, quartzite, and lydite from the conglomerate, or pebbly and gritty bone-bed, of the 'Upper Tunbridge Wells Sandstone' in the quarry at Whiteman's Green, near the town" of Cuckfield, found some which showed in parts "a glaze-like polish" with "delicate parallel striæ" and one with a "triangular shape." He assigned these appearances to the action of blown sand on the shores of the Wealden estuary. The stones were distributed between the museums of Brighton and the Staff College, but are not now to be seen. Chelius and Klemm (1894) have recorded pebbles with sharp ridges and with one or all sides finely polished, from the Middle Bunter conglomerate of Radheim, in E. Odenwald. They regard them as "not unlike" Dreikanter.

The most striking instance of fossil Dreikanter is that described by Nathorst (1886*a*, *b*). Quartz pebbles, having this characteristic shape, and smaller pebbles worn on all sides, are found at Lugnås in Vestergötland in the Eophyton sandstone of Cambrian age. The associated remains indicate that these pebbles lay on a sea-shore, or on sand dunes close to a shore (Nathorst, 1886*c*).

In Britain wind-worn pebbles do not seem to have been noticed often, or else those who have noticed them have not been at the pains to record their occurrence.

Besides the Bowdon pebble, the pebbles described by Prof. Rupert Jones, and the Mount Sorrel surfaces noticed by Prof. Watts, I can find nothing definite, although in the discussion on Enys' paper (1878) Sir John Evans "referred to various examples of stones polished by blown sand occurring in this country."

Mr. S. S. Buckman has searched the neighbourhood of Cheltenham, and has sent me various pebbles, some of which bear traces of wind action, From Bengeworth, near Evesham, in the Avon Valley, where much Northern Drift covers the Lias, come two pebbles 27 and 33 mm. long, of veined quartz and chert respectively, each glazed on the upper surface, the smaller one having a fairly distinct and slightly concave facet. At Beckford, seven miles north of Cheltenham, Mr. Buckman found a red quartzite pebble, 40 × 31 mm., water-worn, but with three facets which have not met so as to form ridges; the difference in form and colour between these red facets and the remaining water-rounded and stained surface is clearly marked. This was found at 130 ft. O.D., loose on gravel consisting of Oolite fragments, and a few Northern Drift pebbles; the gravel lies over sand containing a few fragments of Oolite. Similar sand, similarly situated, at Charlton Kings is false-bedded and composed of rounded grains, and may be blown sand. The soil above the gravel at Beckford is rich in rounded siliceous particles, ·25 to ·5 mm. in diameter. None the less, I am doubtful whether the facets are due to blown sand; had they been so, they would have been more polished, and the rest of the upper surface would not have escaped so entirely: perhaps Berendt's explanation fits this case. A pit near Bredon Railway Station, in the Avon Valley, in a thick bed of Northern Drift pebbles, yielded only one pebble that was at all flat-sided. Two, perhaps three, of the sides have a higher polish than the fourth, and are also more pitted; they may have been wind-worn for a short time. A few pebbles that appear slightly polished, and perhaps facetted, are sent from Haresfield Camp in the Cotteswolds, at 750 ft. O.D., and from Cutsdean Hill in the Cotteswolds, at 1,000 ft. O.D. All these came from the surface of ploughed fields, and we need not suppose any agent other than the blown dust of the fields.

We may now inquire what light the occurrence of facetted pebbles in a geological formation throws on the physical conditions of the period. It has been argued that they imply desert or, at least, steppe conditions. Even so recent a writer as Wittich (1899), in his careful discussion, says: "Everywhere Dreikanter occur, are or were similar climatic and geological relations;" and, again, "Dreikanter are not found isolated or locally

confined to small spots, but scattered over wide stretches of country. The conditions leading to their production must therefore have a similarly general significance." The necessary factors are held by him to be pebble-bearing sand, gravel, or boulder-clay, slightly or not at all covered with vegetation, a dry climate, and strong winds. How far these statements are from approaching the truth is shown by the instances of New Zealand, Fjelkinge, and Watertown. It is, of course, the case that the facetted pebbles of Germany are scattered over a wide area, and their evidence, in conjunction with that of the Loess, and of the animal and plant remains found therein, certainly does point to a steppe period following on the retreat of the glaciers, when the vast plain was covered with loose deposits as yet uncovered by vegetation (see Nehring, 1895; Sauer, 1890; Krause, 1894, and others). On the other hand the instances of Cuckfield and Lugnås imply no conditions very different to those now obtaining on the shore of Liverpool Bay or the beach of Hokitika. Facetted pebbles are in themselves no evidence of steppes or of a dry climate. Each case must be considered on its own merits.

Although some of the instances quoted have seemed to imply certain prevailing winds, yet the observations of Walther and Stone must always be borne in mind. A large number of specimens must be examined *in situ*, and their bearings carefully taken before any opinion can be expressed as to the meteorological conditions of the locality under investigation. It has been remarked that a true Dreikanter at least proves the existence of three prevailing winds, and that this alone may be a point of extreme interest. But we have seen that a Dreikanter may be produced by the action of a single wind, and even that wind may be very variable within limits. In fine, the only unassailable conclusion to be drawn from the occurrence of undisturbed Dreikanter is that the spot was, during their formation, exposed to subaërial action, and was therefore somewhere above the usual sea-level. Their occurrence in numbers under beds of sand may suggest that these latter are subaërial deposits, but is not convincing proof, since a shore exposed for a time to wind action may softly sink beneath the sea, and its facetted pebbles may be covered with sand by marine currents. Such seems to have been the case at Lugnås. This has led Woodworth (1894) to suggest that pebbles and boulders dredged up should be scrutinised to see if they bear marks of æolian erosion, as they would then be evidence of the sinking of the land.

To return at last to the Bowdon pebble. The beautifully preserved surface and the clear distinction between the wind-worn and water-worn portions are evidence enough that this was not facetted prior to its deposition in the Bunter Beds. On the contrary, though testimony as to position in the section is wanting, everything goes to show that it was fashioned on the spot where

it was found. It bears all the characters of a wind-worn pebble: the facets, the polish, the minute pitting and slight grooving, the concavity of two facets. But it does not prove the action of more than two prevalent winds. That these winds were two, and that they acted for some continuous time, I infer from the fact that the facets do not coincide with the primitive parallelepipedal form, or rather with so much of that form as appears to have remained after its angles had been removed by rolling among the Bunter pebbles, and again in the glacial drift. The orientation of the pebble being unknown, nothing can be said as to the direction of those winds beyond the fact that they were at an angle of 122 deg. The period when these winds blew cannot have been so remote from our own day that we have any right to imagine the one of them (3) to have been any other than the sou'-wester; and in that case the other (1) would probably have been about E. by 13 deg. S., and having been the dryer wind had more effect.

One swallow does not make a summer, and one pyramid-pebble does not imply a dry climate or steppe conditions. Nevertheless it is interesting to note that this specimen bears much the same relation to glacial deposits and to the subsequent accumulations as do those of Germany and the eastern States of America. Remains of steppe-animals, though known from the southern counties, have not, I believe, yet been found in the drift-deposits of the north of England. The sand is the sole remaining witness. Unfortunately it is not so easy, as it once was thought, to distinguish between water-worn and wind-worn sand. Often all that can safely be said of a sample of sand is that the grains are large or small, are more or less worn. Carus-Wilson (1892) considers mastoid markings on sand-grains to be undoubted evidence of æolian action; but it is not clear that such markings are inevitably present in all blown sands. Mr. Mellard Reade (1892) describes the sand of the Lancashire and Cheshire Boulder Clay as "much rounded, some of the grains being extremely polished." But he finds no difference between the sand of the Crosby dunes and that of the shore, and therefore regards the sand of the Boulder Clay as evidence of marine origin. He tells me that he has examined many sections of Drift all over the country without noticing evidence of æolian action. There is room for further investigation.

The inquiries diligently prosecuted in such time as could be spared since the Bowdon pebble was placed in my hands nearly a year ago, have brought to light no startling novelty. But those who have more opportunity than I for field exploration will doubtless find further examples which may lead to more definite conclusions. It has been in the hope of inciting others to the search, and of aiding them in it, that this paper has been drawn up. If it fails in its object, that will not be the fault of many friends and colleagues who have helped in its preparation—namely, Dr. Geo.

Abbott, Mr. H. Balfour, Mr. H. Bolton, Canon T. G. Bonney, Professor G. S. Boulger, Mr. S. S. Buckman, Mr. R. D. Darbishire, Professor Boyd Dawkins, Professor W. M. Davis, Dr. C. Gottsche, Mr. Upfield Green, Professor T. Rupert Jones, Mr. B. Lomax, Mr. A. Mickwitz, Professor A. G. Nathorst, Mr. G. T. Prior, Mr. Mellard Reade, Mr. C. Davies Sherborn, Mr. L. J. Spencer, Professor W. W. Watts, and Dr. Henry Woodward. To all these, and any who may be left unmentioned, I offer my hearty thanks.

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EXPLANATION OF PLATE XI.

FIGS. 1-4.—From Reval, Esthonia. 1-3 placed in the same orientation as when found. North (magnetic, August, 1897) at the top of the page.

FIG. 1.—Fine-grained hornblende gneiss: *a.* upper surface, all worn and pitted, with clear-cut facet on south, lichen growing on the lower slopes; *b.* under surface, water-worn and iron-stained.

FIG. 2.—Augen-gneiss: upper surface, the quartz standing out in ridges around the rolled orthoclase, the mica eaten away; the south-west side lies almost in the plane of the foliation, so that the ridging is confined to the other two sides; the apex is obliquely truncated; all depressions overgrown by lichen. *Cf.* Diagr. 3, p. 408.

FIG. 3.—A very fine-grained hornblende gneiss: upper surface much polished, with a few slight elevations of quartz; lichen on the lower slopes, forming a band between the wind-worn and water-worn surfaces.

FIG. 4.—Granite, very slightly foliated, but not enough to produce ridging; upper surface, all polished and differentiated; apex obliquely truncated.

FIG. 5.—From Hokitika beach, South Island, New Zealand. Basalt: upper surface showing two main facets and a truncate end; slight furrows cross the stone at right angles to the main ridge.

FIG. 6.—From Bowdon, Cheshire, in Drift. Liver-coloured quartzite derived from Bunter Pebble Beds: *a.* upper surface, showing facets; *b.* under water-worn surface. *Cf.* Diagr. 1 and 2, p. 397.

All figures are $\times \frac{3}{5}$ diam.

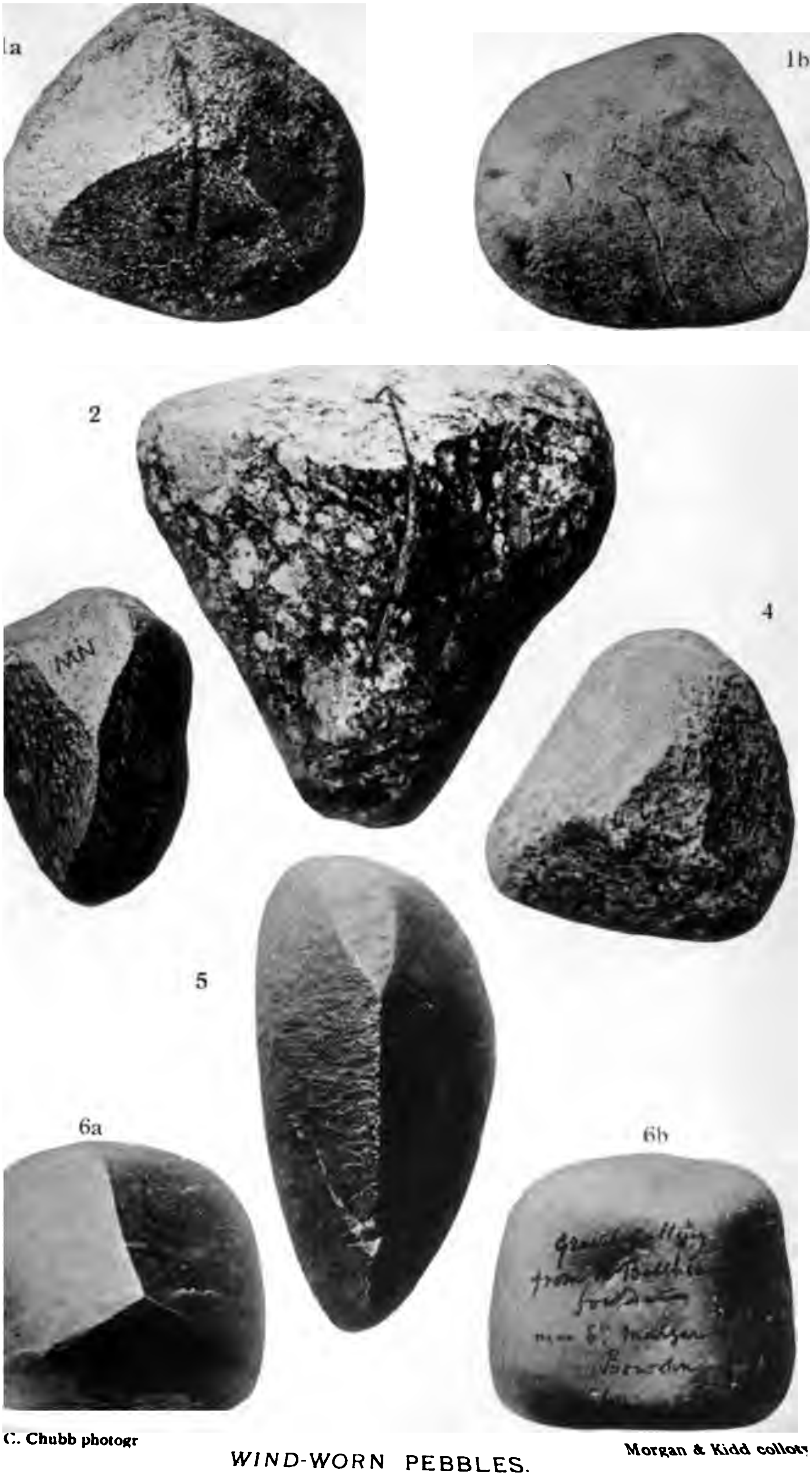
ORDINARY MEETING.

FRIDAY, MAY 4TH, 1900.

W. WHITAKER, B.A., F.R.S., President, in the Chair.

Thomas P. Baldwin, Miss Grace Hacking, B.Sc., Harford J. Lowe, J. B. Morris, Miss E. Pearse, B.Sc., were elected members of the Association.

A lecture was delivered by Mr. Horace W. Moncckton, F.L.S., F.G.S., on "Some Features of the Recent Geology of Western Norway," illustrated by lantern slides.



C. Chubb photogr

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WIND-WORN PEBBLES.

Abbott, Mr. H. Balfour, Mr. H. Bolton, Canon T. G. Bonney, Professor G. S. Boulger, Mr. S. S. Buckman, Mr. R. D. Darbishire, Professor Boyd Dawkins, Professor W. M. Davis, Dr. C. Gottsche, Mr. Upfield Green, Professor T. Rupert Jones, Mr. B. Lomax, Mr. A. Mickwitz, Professor A. G. Nathorst, Mr. G. T. Prior, Mr. Mellard Reade, Mr. C. Davies Sherborn, Mr. L. J. Spencer, Professor W. W. Watts, and Dr. Henry Woodward. To all these, and any who may be left unmentioned, I offer my hearty thanks.

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EXPLANATION OF PLATE XI.

FIGS. 1-4.—From Reval, Esthonia. 1-3 placed in the same orientation as when found. North (magnetic, August, 1897) at the top of the page.

FIG. 1.—Fine-grained hornblende gneiss: *a.* upper surface, all worn and pitted, with clear-cut facet on south, lichen growing on the lower slopes; *b.* under surface, water-worn and iron-stained.

FIG. 2.—Augen-gneiss: upper surface, the quartz standing out in ridges around the rolled orthoclase, the mica eaten away; the south-west side lies almost in the plane of the foliation, so that the ridging is confined to the other two sides; the apex is obliquely truncated; all depressions overgrown by lichen. *Cf.* Diagr. 3, p. 408.

FIG. 3.—A very fine-grained hornblende gneiss: upper surface much polished, with a few slight elevations of quartz; lichen on the lower slopes, forming a band between the wind-worn and water-worn surfaces.

FIG. 4.—Granite, very slightly foliated, but not enough to produce ridging; upper surface, all polished and differentiated; apex obliquely truncated.

FIG. 5.—From Hokitika beach, South Island, New Zealand. Basalt: upper surface showing two main facets and a truncate end; slight furrows cross the stone at right angles to the main ridge.

FIG. 6.—From Bowdon, Cheshire, in Drift. Liver-coloured quartzite derived from Bunter Pebble Beds: *a.* upper surface, showing facets; *b.* under water-worn surface. *Cf.* Diagr. 1 and 2, p. 397.

All figures are $\times \frac{3}{8}$ diam.

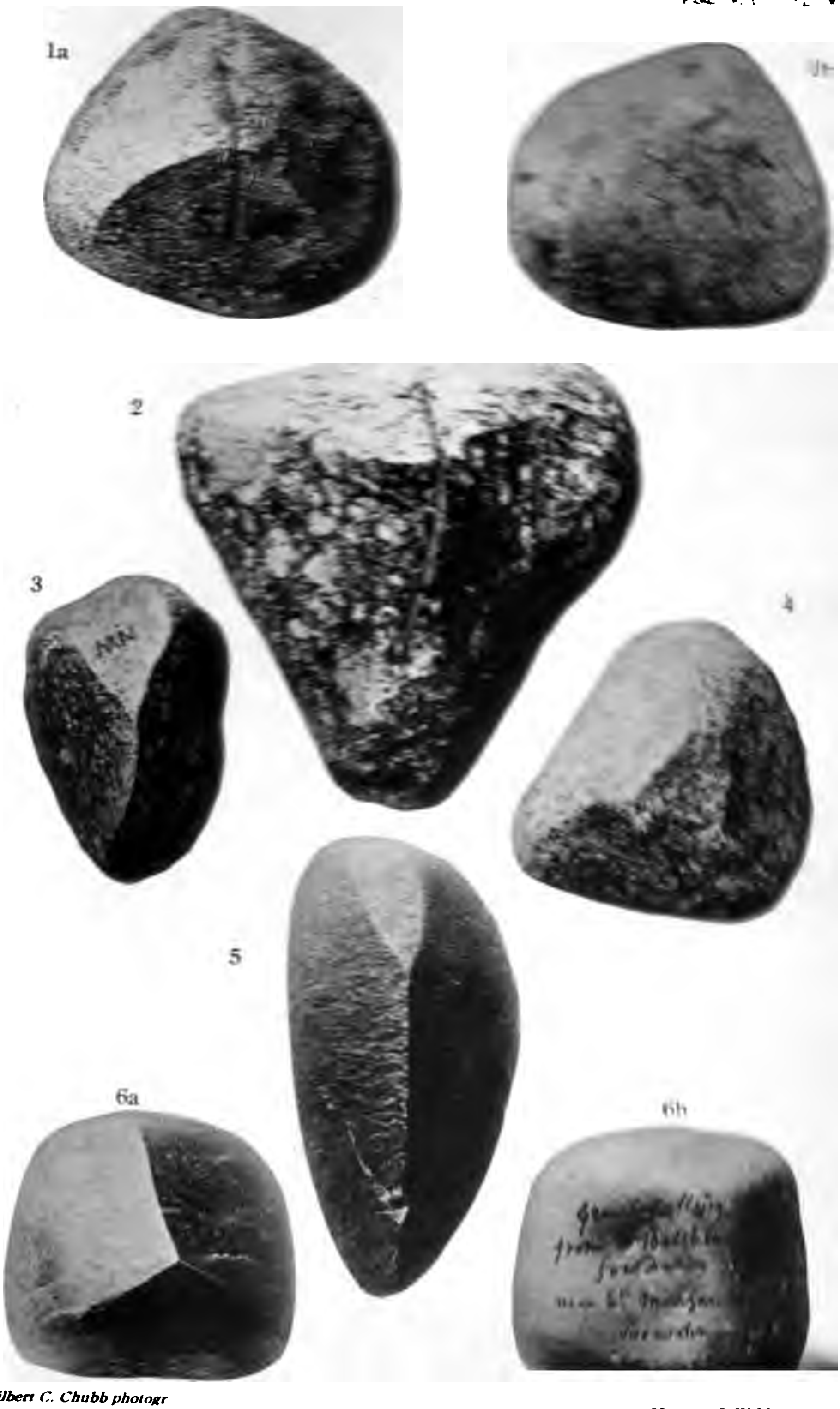
ORDINARY MEETING.

FRIDAY, MAY 4TH, 1900.

W. WHITAKER, B.A., F.R.S, President, in the Chair.

Thomas P. Baldwin, Miss Grace Hacking, B.Sc., Harford J. Lowe, J. B. Morris, Miss E. Pearse, B.Sc., were elected members of the Association.

A lecture was delivered by Mr. Horace W. Monckton, F.L.S., F.G.S., on "Some Features of the Recent Geology of Western Norway," illustrated by lantern slides.



Gilbert C. Chubb photogr.

WIND-WORN PEBBLES

Morgan & Kidd

A NEW RHÆTIC SECTION AT BRISTOL.

By W. H. WICKES.

(Read January 5th, 1900.)

IN 1891 the late Edward Wilson described a new section at Pylle Hill, Bristol, and stated that: "Although the Rhætic rocks have a wide horizontal distribution in the neighbourhood of Bristol, it is but seldom that they are exposed at the surface. In the absence of natural inland sections, and of quarries on the horizon of a thin series of rocks which yield no minerals of commercial value, we have generally to trust to new railway cuttings or other artificial excavations for affording us opportunities for their examination." "A redescription of the Pylle Hill section therefore appears desirable whilst it is in a fresh state. In a very short time the new cutting, which, like the old one, is sloped at so high an angle as to be almost inaccessible, will become obscured by rain-wash and vegetation, and thus be no longer available for detailed examination."*

The foregoing remarks so accurately represent the state of the Rhætic Beds in Bristol and its suburbs, as to make them worth quotation. All the sections hitherto described are now built upon or otherwise inaccessible. It is therefore thought that a description of a new section may be of interest. Some fields to the north of Bristol, near Redland Green (about 2½ miles north-west of the Pylle Hill cutting), have been lately laid out for building purposes under the name of "New Clifton," and a low hill, on which Coldharbour Farm stands, has been cut through for the main road, exposing Lower Lias, Rhætic, and Upper Trias Beds. The two first are well exposed, but the dip is difficult to determine owing to slight anticlinals which give the beds a wavy appearance. It is believed, however, that the beds dip about 2 or 3 deg. to the N.N.W. The cutting is from 5 to 7 ft. in height, and is on a slope. By measuring at several points the following section has been obtained:

REDLAND (NEW CLIFTON) SECTION.

			ft.	in.	
LOWER LIAS.		Six Beds of hard Limestone with clay partings	3	0	*Ammonites planorbis*, *A. johnstoni*, *Ostrea liassica*, *Pentacrinus*, *Pleuromya*, *Nautilus striatus*, *Cidaris* spines.
	q	Rubbly Limestone	0	7	
WHITE LIAS.	*p*	White shaly Limestone, with occasional seam of hard conchoidal Limestone	0	9	*Monotis decussatus*, *Modiola minima*.
	o	*Clay parting*	0	1½	

* *Quart Journ. Geol. Soc.*, 1891, vol. xlvii, p. 545.

	Bed	ft.	in.	
UPPER RHÆTIC.	*n* Compact conchoidal Limestone, with "Landscape" Markings (Cotham Marble)	0	8	*Modiola minima* and small turbinate Gasteropod (undetermined).
	m Laminated blue and brown clay (weathering greenish-grey), with two white calcareous bands, and some dark-brown septaria	2	0	Vertebra of *Plesiosaurus*, small Ostracods (*Darwinula ?*).
	l Cream-coloured shaly Lime- *k* stone, with blue core and occasional greenish-grey septaria	2	2	Fish remains, teeth, and scales of *Saurichthys*, *Gyrolepis*, *Pholidophorus*, Insect wings, *Estheria minuta*, *Darwinula leguminella ?* *Pecten valoniensis*, *Cardium rhæticum*, *Naiadites acuminatus*.
	i Dark bluish-green crystalline Limestone	0	8	
Avicula contorta-Beds.	*h* Dark brown and black shaly clay	0	5	*Avicula contorta*, *Pecten valoniensis.*
	g Dark crystalline Limestone	0	4	*Axinus cloacinus.*
	f Black shales and clay	3	0	*Cardium rhæticum.*

Base of section. The black shales probably go down another 5 ft.

The Tea-green and Red Marls crop out a short distance away, but the junction is not at present opened up.

Of the sections previously recorded, that of "Pylle Hill," described by E. Wilson, most nearly resembles this one, therefore the marginal letters used by him in specifying the various beds, have been added for purposes of identification and comparison.

Owing to the thinning out of some of the beds, and also to changes in the composition of others, this correlation in some cases is only approximate. Mr. Wilson's section shows 17 ft. of Rhætic beds at Pylle Hill. This section (allowing for 5 ft. unexposed) gives only about 14 ft., the principal loss occurring in bed "*m*," which measures 2 ft. as against 4 ft. 11 in. in E. Wilson's section.

Many of the beds are of the usual Rhætic character and require no special comment, but the bed "*k*" is interesting, being in some zones full of the little water plant *Naiadites acuminatus* in a fine state of preservation.* In the same bed occur two or three layers of crushed shells (principally *Cardium rhæticum*), amongst which are found fragmentary elytra of beetles. In many cases these are only casts, the original chiton having disappeared. One seems to be a larval form, probably of a Lampyrid beetle. In the same bed parts of a head of a fish, referred to *Pholidophorus* by Mr. Smith Woodward, have been noted.

There does not appear to be any definite "bone-bed" as at Aust Cliff, but teeth and scales of fish are scattered through the section. At some horizons they are more plentiful, but bones are rare, and when found are very minute.

The bed "*n*," of Cotham Marble, is the best development

* Mr. A. C. Seward has kindly promised to examine this new material.

the writer has seen of this curious rock, some hundreds of blocks having been exposed in the excavation. The thickness is unusual, varying from 4 to 11 in. Many of the larger blocks have double "landscapes." One of these has been polished, with very satisfactory results, and is now in the Museum of Practical Geology. Nearly all the rest, however, have been used for road-making.

The list of fossils given in this section could easily be extended, as many are still undetermined, but it was thought advisable to record only such as were well defined and recognisable.

In certain parts of these beds—usually lining crevices in the rocks—small portions of the rare mineral known as "Baryto-Celestine" occur. It is usually in a decomposed state and breaks up into a fine powder. Some distance from the section a small deposit was found by the writer containing some very good unweathered crystals, but the bed is now worked out. This rare mineral was noted by Dr. Norman Collie as occurring in the Trias, near Clifton Down Station, some twenty years ago.* It does not appear to have been noticed since. Last year the writer found some small pieces in the Trias, and also traces of it in the Millstone Grit of Clifton, but it has not been noted, hitherto, from the Rhætic. It is reported that Bristol is the only British locality.

"Baryto-Celestine," apart from its chemical composition, differs from ordinary "Celestine" in the following characters: Its crystals are mostly opaque, but occasionally transparent, radiate, or divergent, the angles obscure. It is much more brittle than the true celestine, weathers to a soft, powdery substance, almost as fine as Fuller's Earth, but which still shows the radiate structure. It occurs in cracks and fissures, and is evidently a secondary deposit.

VISIT TO THE MUSEUM OF THE GEOLOGICAL SOCIETY OF LONDON.

SATURDAY, FEBRUARY 10TH, 1900.

Director: C. DAVIES SHERBORN.

(*Report by the* DIRECTOR.)

A LARGE party having assembled in the Museum, the Director pointed out that the collection dated from 1807, and had been slowly accumulating until about ten years ago, when pressure of space had prohibited further additions. The collection consisted of figured types, specimens referred to in the Society's

* See *Proc. Bristol Naturalists' Soc.* (N.S.), vol. ii, 1879, p. 292; also the *Mineralogical Magazine*, vol. ii, 1879, p. 220.

publications, historical collections, and miscellaneous material. It was especially rich in foreign specimens, which were arranged geographically. The British specimens were arranged stratigraphically. The collections had been partially catalogued by Lonsdale, B. B. Woodward, and others, and completely by the Director between 1890—1898. There had been no proper Curator for many years, and consequently the collections were in a dirty and uncared-for condition, but owing to the watchful care of Mr. Wm. Rupert Jones who had for years kept an eye on the cabinets, the specimens had not suffered in any other way. It is impossible for officers, already considerably overworked, to do the necessary work of such a valuable collection.

The principal collections exhibited and explained to the visitors were the following: the McEnery types from Kent's Hole, 1826; Agassiz's types of fishes from the Carboniferous of Ireland; types of Murchison's "Silurian System"; Sacrum of *Megalosaurus*; Dr. Hicks' large *Paradoxides*; D'Archiac and Haime's "Nummulitique de l'Inde" types; Hislop's Indian types; Bain's and Grey's S. African types; Marcou's types of the "Geology of North America," lost to sight for thirty years, and in consequence affording a serious bar to the progress of North American geology; types of St. Domingo Tertiaries; D. Forbes' specimens from the Bolivian Andes; T. L. Mitchell's Australian collection, the first collection received from Australia; his types of Australian cave-mammals; Duncan's types of Australian Miocene corals; and Sharpe's types of Tertiary and Silurian fossils. Buckland's Rhinoceros from Lawford, and the Granite boulder from the Chalk of Haling, Croydon (not Purley as always erroneously quoted). Other curiosities, such as Wm. Smith's Map and Table of Strata, Moran's beautiful picture of the hot springs of the Yellowstone, and the portrait of Mary Anning, were also referred to.

The President, Mr. Whitaker, in his remarks referred to the interesting fact that for the first time in the history of the Association, and of the Society, he held the position of President of both bodies, at one and the same time, for that particular month, and that the two bodies had just interchanged presidents, a fact that was enthusiastically received. The usual votes of thanks were passed, and the members of the Association were much pleased at the generosity of the Society in allowing them to inspect their collection. It was hoped that at an early date the collection would find a home in some public building, where they could be available to all students.

EXCURSION TO NEWTON ABBOT, CHUDLEIGH, DARTMOOR, AND TORQUAY,

EASTER, 1900.

Directors: HORACE B. WOODWARD, F.R.S., F.G.S., A. R. HUNT, M.A., F.L.S., F.G.S., AND W. A. E. USSHER, F.G.S.

Excursion Secretary: PERCY EMARY, F.G.S.

(*Report by* THE DIRECTORS.)

I.—NEWTON ABBOT, BOVEY TRACEY, AND CHUDLEIGH.

BY H. B. WOODWARD.

DURING the Easter excursion of 1899 the members of the Association examined for the first time the coast of South Devon from Seaton to Exmouth, and proceeded from Exeter as far as Great Haldon.* On the present occasion they investigated a further portion of South Devon, to which no excursion had previously been made, except on one occasion, July 23rd, 1884, when, under the guidance of William Pengelly, and during the presidency of the late Dr. Hicks, the members proceeded from Plymouth to Torquay for the day, saw the coast at Hope's Nose, and visited Kent's Cavern.†

On *Thursday evening*, *April 12th*, the members of the party arrived at the Globe Hotel, Newton Abbot.

On *Friday*, *April 13th*, they started at nine a.m., and were driven through the old town of Newton Bushel to the hill on which Knowles Quarry is situated. Here was to be seen an intrusive mass of ophitic dolerite or diabase (with chlorite), which had produced a spotted alteration termed "Spilosite," on the adjacent Upper Devonian slates. Much of the diabase was in a decomposed state, and the Director remarked that it was a good instance of the rotten nature of much of Devonshire, a state due to prolonged weathering, and which added greatly to the difficulties of geological mapping. The igneous rocks formed many isolated knolls in the district, and this appeared to be due not altogether to their hardness, but partly to their porosity after decay. They rose up like outliers of Bagshot Sand in a London Clay area. Nevertheless they had their uses, for while the solid rock at a depth provided road-metal, the deeply-rotted portion was a water-bearing bed, and gave out springs. Among the fossils noted from the slates by Mr. Ussher were *Posidonomya venusta*, Trilobites of the genus *Phacops*, and Ostracods. The beds belonged to the division known as the *Entomis*-slates (or Cypridinen-schiefer).

* *Proc. Geol. Assoc.*, vol. xvi, p. 133.
† *Proc. Geol. Assoc.*, vol. viii, p. 472.

The party was then driven on by Blatchford and Forges Cross to Sandpit Copse, south of Lower Staplehill. Here, at an elevation of 223 feet, was a sand-pit showing highly-inclined beds of sand and gravel, with pipe-clay and traces of coloured clays, dipping towards the Bovey valley at an angle of about 35 deg., and resting against Devonian slates. The gravel yielded fragments of veined grit, chert, igneous rocks, and more rarely Greensand chert and Chalk flints. This was one of the sections referred to by Mr. Clement Reid in his paper on the Eocene deposits of Devon.

Driving on by Blackpool and Halford, the members were now conducted to the old Lignite Pit by the Bovey Tracey Potteries; a pit rendered famous by the researches of the late William Pengelly and Oswald Heer. The pit was partially filled with water, but the banks showed fine white sandy clays, coloured clay, and coarse sands, with thin flaky lignite bands.

The lignite had been worked since about the year 1714, and was known as the Bovey coal, the thickest bed being about six feet. When burnt, it gave out much smoke and an unpleasant odour. Dr. Falconer had first suggested that the lignite-beds might be of Miocene age, and. through his influence, Pengelly started his explorations with the aid of Mr. Henry Keeping. The section was then cut clear, and they were enabled to examine over 100 feet of the strata which dip to the south at 5 deg. The plant-remains were examined by Dr. Heer, who regarded them as Miocene, and as akin to those of the Hempstead (Hamstead) Beds of the Isle of Wight. More recently Mr. J. Starkie Gardner had shown that the flora was practically identical with that of the Bagshot Beds of Bournemouth. The lignite was mainly composed of coniferous wood, and among the species identified, the *Sequoia couttsiæ* was noteworthy. The oaks, laurels, figs, and cinnamons of Bovey were identical with those of Bournemouth.* No animal remains, with the exception of one insect, had been found in the deposits.

As originally pointed out by De la Beche, the strata had been deposited in a large lacustrine area, the clays (an impure china-clay) being due to the decomposition of the felspars, and the sands being derived from the quartz of the Dartmoor granite.†

Driving across Bovey Heath, the members next visited the large clay-pit belonging to Messrs. Candy & Co., at the Great Western Potteries, near Heathfield Station. Here a variable series of grey and white clays, carbonaceous sands, and occasional lignite-beds was to be seen. It was mentioned that a boring had been carried to a depth of 520 feet from the surface through clays, sands, and lignites without reaching the base.‡ The beds here

* Gardner, *Geol Mag.*, dec. ii, vol. vi, p. 153; *Quart. Journ. Geol. Soc.*, vol. xxxv p. 227; xxxviii, p. 3.

† "Report on Geology of Cornwall," etc., pp. 255, 511.

‡ A boring made more than sixty years ago near Bovey Tracey passed through nearly, 300 feet of Bovey Beds.—De la Beche, *op. cit.*, p. 248.

dipped at an angle of about 8 deg. towards the W.S.W. At this pit, Messrs. Candy & Co. manufactured all kinds of sanitary ware, white and coloured glazed bricks, fire bricks, etc.

Elsewhere in the Bovey basin the white pipe-clays and the darker potters' clays were dug and shipped from Teignmouth, not only to the potteries of North Staffordshire, but to various parts of Europe. In 1898, nearly 38,000 tons of clay were dug, the total value being estimated at a little over £18,000.

Attention was drawn to the fact that the surface-layers of the Bovey deposit had here and there been rearranged and redeposited in Pleistocene times, as proved by the discovery, made in 1872 by Dr. Nathorst, of *Betula nana*, the dwarf arctic birch. These remains had been found in the surface deposits in a pit between the Bovey Tracey potteries and those of Heathfield. It was also stated that remains of a canoe had, in 1881, been found in the Heathfield pit, and attention had been drawn to the discovery by Pengelly, who thought that the object was of Glacial age.* There was, however, no reason to assign so great an antiquity to the canoe, for, although the surface was a little over 90 feet above sea-level, and perhaps 40 feet above the level of the adjacent Bovey river, in ancient times there were doubtless pools and boggy places in the broad Bovey valley in which a canoe might have become mired. Indeed, J. G. Croker had remarked in 1856 that, until within the previous ninety years, when it had been drained, the Bovey basin had been almost a swamp.† Moreover, during February, in the present year, exceptionally heavy floods had occurred in the valley, so that the road between Kingsteignton and Newton Abbot became impassable, owing to a heavy snowfall and subsequent thaw, accompanied by heavy and continuous rain. In the old alluvial gravel of the Teign, at the Zitherixon pit, which lies a little west of the road just mentioned, there were discovered, many years ago, a wooden doll (possibly an emblem of phallic worship) and also a bronze spear-head, objects which were kindly exhibited at the Globe Hotel, by Mr. C. D. Blake, of Newton Abbot.

Crossing the river Bovey and the Teign at New Bridge the party was now driven to a newly opened lignite-pit in the "Great Plantation," east of Preston Manor clay works, and a little to the east of the high road between Chudleigh and Newton Abbot. Here an excellent section of the lignite-series with bands of potters' clay had been opened up in proximity to other pits where pipe and potters' clay were extensively dug for Messrs. Watts, Blake, Bearne & Co. The lignite was used for fuel in the stationary engine which worked the machinery employed in the pits. There was no time for a detailed study of these lignite-beds, but the illustration (Plate XII, Fig. 2), from a photograph taken by Mr. A. K. Coomara Swamy, well shows the alternation of potters' clay and lignite.

* *Trans. Devon Assoc.*, vol. xv, pp. 376, 395.
† *Quart. Journ. Geol Soc.*, vol. xii, p. 354.

Mr. Bauerman remarked that the lignite was somewhat similar to the Brown Coal of Tertiary age, worked in various localities on the Continent.

Returning by the high road the members were now driven by Bellamarsh Barton, where, alongside the river Teign, sections of disturbed Culm-measures were to be seen. Alighting near Chudleigh Station, the members were met by Mr. W. A. E. Ussher, who now took up the duties of Director, and also by Col. Walcott, of Rock House. Walking by Lawell House and across Kate Brook, a small section of cherty beds in the Lower Culm-measures was examined. This showed about 12 feet of dark chert beds of the Basement Culm-measures, in which Messrs. Fox and Hinde had found Radiolaria.* Mr. Ussher pointed out the structure of the Chudleigh valley, where the Devonian slates and limestones occur bounded on all sides by faults, bringing them against different portions of the Culm-measures. In the Chudleigh gorge he remarked that the relations of the Devonian slates and limestones were apparently due to the exposure of slates by denudation of the overlying limestones; this however, he considered illusory as the slates seemed to be of later formation than the limestones, and the latter, if not overthrust upon them, would appear to have been formed by coralline growths in clear water at a more rapid rate than the muddy sedimentation which was afterwards slowly accumulated on their margin, so that beds of slate of Upper Devonian age might be banked against limestone of the massive type either of the zone of *Rhynchonella cuboides* or of indisputably Middle Devonian age. This explanation, he said, had been put forward by him ten years ago, to account for phenomena such as the relations of the slates and limestones of Chudleigh gorge, and the outer edge of the Newton Abbot limestones near Chircombe Bridge at their junction with slates.† The Chircombe Bridge limestone was considerably lower in the series than the Chudleigh limestones, and again the Ashburton limestone was separated from the Newton Abbot limestones by slates in part corresponding to the Cypridinen-schiefer, and containing the characteristic Ostracoda of that Upper Devonian group. Hence the connection of the Ashburton and Newton limestones not only demanded a synclinal structure, but also considerable difference in rates of organic growth and muddy sedimentation, unless the limestones were bounded by faults, of which there was not sufficient evidence.

Having proceeded a short way up Chudleigh Glen, the fine crags of Devonian Limestone and the entrance to one of the Chudleigh caves were seen. Col. Walcott then led the party through his picturesque grounds, in which an old quarry and another cavern are situated; then a halt was made at Glen

* See *Trans. Devon Assoc.* vol. xxix, 1897, p. 518.

† *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 513.

Cottage, adjacent to the Palace quarry, and a little above the Chudleigh waterfall. In this quarry fine examples of *Murchisonia* have been obtained.

Mr. Woodward exhibited specimens of *Rhynchonella cuboides* and *Heliolites porosus*, examples of which had been obtained from the Chudleigh quarry.

Mr. Ussher remarked that the occurrence of the Frasnian (lower part of Upper Devonian) shell in the same quarry with the Middle Devonian coral, was parallelled in other well-known quarries, such as those of Wolborough and Lummaton. It appeared that the massive limestones of the Torquay, Chudleigh, and Newton district, which in the Lower Dunscombe quarry and at Petitor were immediately overlain by shaly, irregular, liver-coloured limestones, containing Upper Devonian Goniatites, such as *G. intumescens* and *G. sagittarius*, represented the basement Upper Devonian beds of the Continent, viz., the massive limestones of the zone of *Rhynchonella cuboides*, but in Devon there was a blending of Middle and Upper Devonian forms in them. If there were not a blending the fact of the discovery of fossils characterising different horizons in the same quarry must be ascribed to plications which in the massive limestones cannot be traced, but are nevertheless scarcely ever absent from the Devonshire Devonian rocks.

Driving then through the town of Chudleigh, and down the narrow street by the Town Mills to Biddlecombe Cross, the members again alighted, and walked eastwards to the lane leading downhill towards Waddon Barton. Here they examined the lower beds of Culm-measures, rendered classic by the labours of the late J. E. Lee and Dr. Henry Woodward. The section was somewhat overgrown, but the party succeeded in bringing to light many specimens of the characteristic even-bedded reddish brown stone, which being split along the direction of the bedding surfaces, revealed traces of the characteristic Goniatite, *G. spiralis*, portions of *Phillipsia*, and traces of *Posidonomya*. Mr. Ussher showed the position of the beds in faulted contact with the prolongation of the Chudleigh limestone on the north and south, the limestone on the south side passing under green Upper Devonian slates at Waddon Barton.

The time spent in exploiting the lane unfortunately necessitated the abandonment of the visit to the Lower Dunscombe quarry which, situated between converging faults, is very near Waddon Barton lane. There the "Goniatite-Beds," red shales and limestones with *Goniatites intumescens*, overlie limestone with *Rhynchonella cuboides*, etc.*

Rejoining the carriages, the party was now driven through the picturesque grounds of Ugbrooke Park, by kind permission of

* *Quart. Journ. Geol. Soc.*, vol. xlvi, pp. 507, 511

Baron Clifford of Chudleigh. The conglomeratic sandstones of the Culm-measures were noticed by some of the members.

Passing Babcombe, a halt was made at Fosterville, and most of the members, under the guidance of Mr. Woodward, walked by a pleasant lane and then across country, through woodland, moor, and marsh, to the Lappathorn Clay pits, and on to Abbrook. Here evidence was seen of the interbedding of gravel with the white clays of the Bovey Beds, the whole overlain by a head of coarse ferruginous gravel which became thicker towards Abbrook, and appeared to be rearranged gravel, not, however, far removed from its parent source. From Abbrook, the party was driven through Kingsteignton to Newton Abbot.

II.—Lustleigh and Dartmoor.

By A. R. Hunt.

On *Saturday, April 14th,* the members took the 9.43 a.m. train from Newton Abbot to Lustleigh. [At Newton Abbot they were joined by Mr. and Mrs. A. R. Hunt, Bishop Mitchinson, the Rev. G. F. Whidborne, and Mr. A. Somervail.] Leaving Lustleigh Station, they proceeded by Rudge and Hisley to the weir near the junction of Becka Brook and the River Bovey. A halt was called at Rudge, to point out the railway-cutting in which the Culm rocks come into abrupt contact with the fine schorlaceous granite commonly known as elvan. In Hisley Wood, the party passed from the ordinary Dartmoor granite over an obscured junction to the Culm. A quarter of a mile beyond the weir, the Becka Brook was crossed by a footbridge near the point of Houndtor Ridge, a remarkable *arête* of Culm grit dividing the valleys of the Bovey and the Becka. The ascent of the Ridge, some 500 feet, along a steep and narrow pathway, afforded beautiful views on either side. It was pointed out that both the quartz-veins and elvan-veins in the Culm shared with the main granite and elvan the characteristic of containing fluid inclusions with chlorides. At the summit of the Ridge (Water Rock on the old 1-inch map, nearly 800 feet above sea-level) the Culm rock is intersected by numerous elvan veins which were carefully examined.

Leaving Water Rock, the party proceeded by Becka falls, and the Rev. Preb. Wolfe's private drive (by kind permission), to Houndtor, noticing on the way a remarkable contact of fine and coarse granite in a roadside block, and some torrential rubble drift between Leighon and Houndtor farm. Arrived at Houndtor, luncheon baskets and sandwiches were in immediate request, after which the party climbed to the top of the tor, which is about 1,200 feet above sea-level. Several Dartmoor questions were forthwith discussed.

The Director made some observations on the origin of tors, and

Mr. Teall (President of the Geological Society) discoursed on the petrological characters of the Dartmoor granite.

Mr. Woodward remarked that not far off, near Hay Tor (or Heytor), there had been an iron mine where magnetite occurred interstratified with the altered shales and sandstones of the Culm-measures. According to Prof. Le Neve Foster, the iron-ore, originally brown hæmatite, had been altered by the granite, as also had the associated strata. The altered rocks contained hornblende and actinolite, garnets, pyrites, etc., also a mineral named Haytorite, which was chalcedony pseudomorphous after datholite.[*]

Mr. Somervail drew attention to the fact that in the great expanse of Dartmoor, where there were no distinct evidences of glacial action, there were no tarns, whereas such sheets of water were common in the glaciated regions of Scotland.[†]

Mr. W. P. D. Stebbing referred to the discovery of blocks of granite in the Chalk of the south-east of England. It had been suggested that some of these boulders had come from Dartmoor, but Prof. Bonney considered this place of origin most improbable.

The members now proceeded across the moor to a granite pinnacle known as Bowerman's Nose, and the opportunity wa. taken to photograph the rocks. The accompanying view (Pl. XII, Fig. 1) is from a photograph by Mr. H. Preston. Thence the route led through Wingstone and Manaton (Half Moon) to Foxworthy [the country cottage belonging to Mr. and Mrs. Hunt, where an excellent tea had been most kindly provided].

The Director, with the vanguard of the party, pressed on to examine some large mounds of rounded rubble in Peck Pits, and also a Hut circle. The field which contains this Hut circle is called the Maryhay—a curious survival of Saxon times, viz., the "merihay" or boundary hedge. It still is the boundary hedge, and the only non-natural boundary of the little farm on the east side of the river.

Many Hut circles have been observed on Dartmoor, and they are regarded as foundations of early habitations. Some of them had stone walls four or five feet high, which were used probably to support wooden poles and a roof of rushes. Flint flakes, scrapers, and cooking-stones have been found in the Hut circles, but no metal implements and no pottery.

A hearty vote of thanks having been accorded to Mrs. Hunt, the return journey was made by Raven's Tor and Lustleigh Cleave to Sharpitor, the Nut Crackers (a logan stone), and Lustleigh Station.

On the way the party first inspected a felspar-quartz-schorl

[*] *Quart. Journ. Geol. Soc.*, vol. xxxi, p. 628.
[†] *Trans. Devon Assoc.*, vol. xxix, p. 386.

vein *in sitû*, the minerals being those of the elvans, but the structure not granitic.

Then two small but deep rock-basins attracted attention. Similar to pot holes in streams, these basins were clearly formed by the solvent action of rainwater, probably acidulated by the decay of lichens and other vegetation.

Lastly, a split block of granite attracted much attention, presenting as it did an exceptional number of Dartmoor problems, such as concretions of two sorts, latent planes of weakness, dissolution of orthoclase crystals, twin crystals of orthoclase, and rearrangement of minerals.

III.—Watcombe.

By H. B. Woodward.

On *April 15th* the members proceeded by train from Newton Abbot to Kingskerswell, whence the road was taken by Kingskerswell Cross and Barton Cross to the Mincent Hill quarries at Barton. Here the Devonian Limestone was well exposed, and yielded numerous corals. From this locality and the adjoining quarries at Lummaton, the Rev. G. F. Whidborne had obtained many fossils, figured and described in his Monograph, published by the Palæontographical Society. While the mass of the Limestone is Middle Devonian, part of it is regarded as probably Upper Devonian by Mr. Ussher. An interesting coral-breccia was noted by him.

After passing near the Watcombe Terra Cotta Works, the members took lunch at the "Palk Arms," and then proceeded by Easterfield Lane to the grand cliffs of New Red sandstone and conglomerate at Watcombe. A fine view was obtained of the red cliffs looking northwards towards Teignmouth and Exmouth. The Director called attention to the Teignmouth pebbles, which, as sold to the public, were polished pebbles of fossiliferous Devonian Limestone obtained from the conglomerate on the beach. The curious coating of annulated chalcedony, named beekite after Dr. Beeke, a former Dean of Bristol, was obtained on the coast.

The lowest division of the New Red Series, the Watcombe Clay, was faulted on the south against the Red Conglomerate.

Passing round to Watcombe Head, and along the northern margin of the Valley of Rocks, the path became for a time obscure; but after scrambling through a fence, and traversing some private grounds, the members reached the high road near Maidencombe House. Thence the way led through Higher Rocombe to Haccombe Cross (524 feet), whence a fine view of Dartmoor was obtained. After walking through the picturesque village of Coffinswell, the large gravel pit in Harpin's Brake, near Aller Farm, was visited; and farther on, past the Aller Vale

Potteries,* another gravel pit was seen. In both places there was much coarse flint gravel inclined towards the valley, and including in places layers of white clay, and coloured sands, which tended to correlate them with the Bovey Beds.

The members returned to Newton Abbot by Ford House.

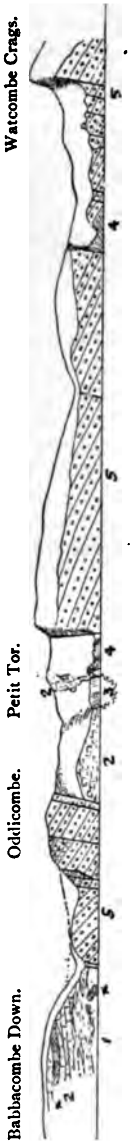
IV.—Babbacombe and Kent's Cavern, Torquay.

By W. A. E. Ussher and A. R. Hunt.

April 16th.—The members took train to Torre Station, and were thence driven to Petitor. On arrival at Petitor rock (300 feet above sea-level) Mr. Ussher pointed out the features of the valley. The limestone knoll of Petitor was examined, and found to consist of closely matted corals. From the knoll the limestone was shown to attenuate in a narrow ridge seaward, terminating on the beach in a pinnacle of shattered limestone penetrated by infiltrated materials from the overlying New Red rocks. These New Red rocks, consisting of clays with sandy bands (really composed of triturated Devonian slates), and brecciated at the base, were seen resting directly on the limestone and faulted on the north against the breccio-conglomerates with large limestone fragments, which forms the fine, commanding crags bounding Petitor Combe on the north. Mr. Ussher pointed out the relations of the Watcombe clays to these breccio-conglomerates. The upper part of the Watcombe clays pass under the conglomerates which form the crags of Watcombe Combe, the lower beds of the clay series exposed in Petitor Combe being separated from them by an intervening mass of the conglomerate faulted down on both sides. The breccio-conglomerates pass conformably under the rubbly breccias with quartz porphyry boulders seen last Easter between Exeter and Haldon.

Turning to the Devonian rocks, Mr. Ussher showed that the lower part of the Petitor valley consisted of red Upper Devonian slates bounded by limestones on both sides. He said that the apparently horizontal character of the limestone on the south side had always been taken as evidence of an anticlinal structure broken by denudation and exposing underlying slates. From a close study of the characters of the Upper Devonian slates of the area, he had been led to doubt the truth of this anticlinal structure, which was figured by De la Beche, and after careful investigation he had discovered traces of the liver-coloured shaly limestones of Lower Dunscombe at the junction of the slates and limestones on either side, and was also fortunate enough to obtain Goniatites, including *G. sagittarius*, in them. He showed that the apparent horizontality of the limestone between Petitor Combe and Oddicombe beach was due to close zig-zag (corkscrew-like) contortions in the vertical limb of the syncline on that side, whilst the shattered character of the limestone ridge on the opposite side

* The clay here used is mostly obtained from the Bovey Beds at Kingsteignton.



COAST SECTION FROM BABBACOMBE TO WATCOMBE (*W. A. E. Ussher*).

3. Upper Devonian Slate.
2. Upper and Middle Devonian Limestone.
1. Middle Devonian Slate.
5. Red breccia and conglomerate } Permian.
4. Watcombe Clay }
× Ophitic Dolerite (Diabase).

of the syncline rendered the detection of bedding planes impossible. In both limestones the structures (fibro-crystalline calcite veins) called "stromatactis" by Dupont were shown to occur; and in the intervening slates *Posidonomya venusta*, a characteristic local Upper Devonian fossil. was obtained. On reaching Oddicombe sands the party were shown a faulted junction between Devonian limestone and New Red breccio-conglomerates. In the breccio-conglomerates local beds of sand were pointed out, the junction of the materials affording pretty examples of contemporaneous erosion.

Mr. Hunt pointed out that after easterly gales Oddicombe beach often affords a good example of the general rule that large beach-shingle will travel in the direction of the wave-stroke along the beach, whereas sand and small shingle, remaining in the grasp of the wave, will travel with the current, which as likely as not is in the reverse direction. Although the Oddicombe limestone-shingle is at the foot of the New Red limestone conglomerates, the cliffs have not supplied the shingle; which is really derived from the *débris* tipped into the sea at the great Devonian Limestone quarry near Anstey's Cove.*

Mr. Hunt, turning to the cliffs, remarked that the conglomerates were too angular and irregular for marine action, and on too vast a scale for river action. He knew of no agency to which they could be attributed. Mr. Teall at once pointed out that similar accumulations were known in the Himalayas, where the disintegration of strata exceeded the available transport; the conglomerates were torrential Mr. Hunt observed that he had not ventured to use the word torrential for phenomena on so grand a scale, being unaware of any recent examples, but that he gratefully accepted, and fully acquiesced in Mr. Teall's explanation.

* See *Trans. Roy. Dublin Soc.*, vol. iv, 1885, p. 283.

Mr. Ussher, in resuming, showed that the dips in the breccio-conglomerates, in places amounting to over 40 deg., were due to faults. He considered that the series was the same as that of Watcombe and Petitor crags let down on either side by faults. On the south side the New Red was shown in faulted contact with dark slates visible in and at the base of the tumbled under-cliff materials, as far as the Cary Arms. The party ascending the cliff by the path was shown the well-bedded limestones (Middle Devonian) of Babbacombe with a bolster-like mass of igneous rock, probably in part decomposed schalstein exposed on the axis of a uniclinal curve. In this connection Mr. Ussher pointed out the structure as a nearly vertical contact of limestones with contemporaneous igneous rock zigzagged by numerous folds, and dark slates with masses of ophitic dolerite (diabase) probably intrusive in them in several places. These bedded limestones and dark slates, he said, were lower in the series than the Petitor limestones on the north and the massive limestones of the Cary Arms coast against which they are faulted on the south; a patch of decomposed and broken red igneous rock at the little boat pier at the Cary Arms being in the vicinity of the fault.

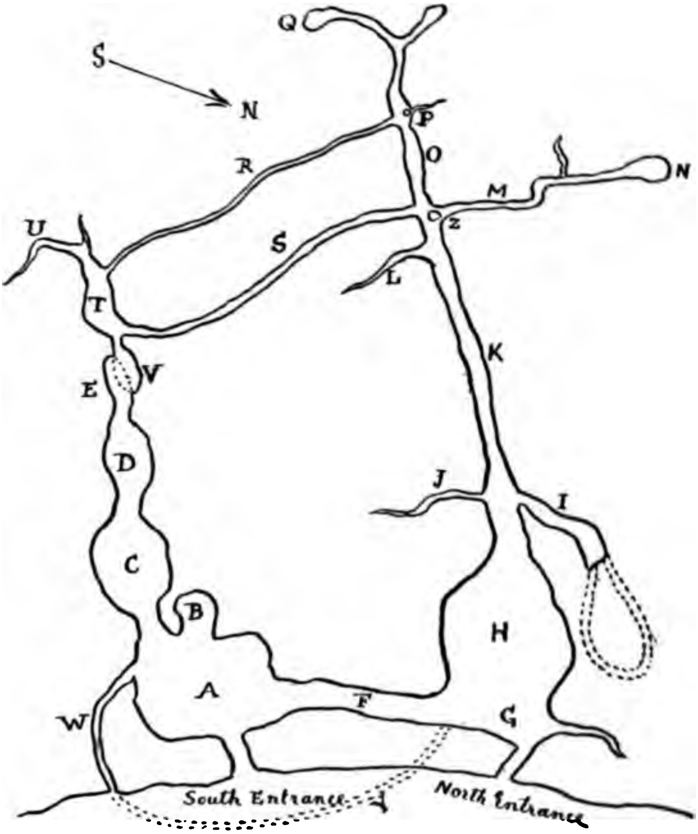
After much needed refreshment at the Cary Arms, the party ascended the hill to the level of Babbacombe Downs, under the guidance of Mr. Hunt, and observed a shallow valley about 400 feet across, draining landwards, it having been truncated by the erosion of the great West Bay. This valley passes at the foot of the Kent's cavern hill and debouches into Torbay. It completely isolates the limestone plateau between Babbacombe and Anstey's Cove. This plateau is the highest of a series described by Pengelly as terraces of denudation, which further occur in descending order, at Daddy Hole Plain, Waldon Hill, and Berry Head, in which neighbourhood Permian dykes are levelled with the limestone, indicating that the era of denudation is post-Permian. In the Walls Hill quarry, through which the valley passes, the Association examined the process of the formation of caves by the enlargement of joint planes, and the origin of cavern accumulations by the infilling of clay, with occasional foreign pebbles, from the surface of the plateau; the arrival of the pebbles on the isolated plateau apparently antedating the erosion of the shallow truncated valley. The limestone was seen to be traversed by joint planes intersecting roughly in the direction north and south, and east and west, perhaps more nearly north-east and south-west.

At Anstey's Cove the party was divided, and Mr. Hunt conducted the first division to Kent's Cavern. While the candles were being prepared, he mentioned some of the surprising theories of cavern critics, *e.g.*, that the extinct cave-mammalia were introduced by the Romans to work in the mines!* On entering the cave the visitors assembled in the Great Chamber.

* See *Trans. Devon Assoc.*, vol. xv, p. 485.

Large as it is, it must on no account be taken as representative of the cavern as a whole; as in it the two most interesting and ancient deposits—the crystalline stalagmite and its subjacent breccia—did not occur at all; nor was their existence suspected until after the Great Chamber had been explored. Passing through this chamber the party entered in single file the "Gallery," to inspect an interesting basin with corrugated sides and divisions formed by the ripples created by falling drops of water. This is the very latest stalagmite in the cave, as it was in process of formation when the explorers found it. The "Gallery" is crossed by a ceiling of the old stalagmite and its history is as follows: First nearly filled with "breccia," this deposit was covered by an old stalagmite floor. The breccia was cleared out and "cave-earth" introduced. The cave-earth in turn was covered by the newer stalagmite, under the older. This little chamber nonplussed the early explorers, who were naturally entirely ignorant of the existence of the ancient stalagmite and breccia. Leaving the "Gallery," the party passed in single file into the "Water Gallery," under the ancient stalagmite floor, in which bones of bear are embedded. At this spot there occurred the first "palæolith" flint-fragments which so astounded the explorers.* After a glance at the vestibule, the site of the "black band," and its bone tools, the party proceeded to the Wolf's Den, where MacEnery found *Machærodus latidens*; a find greatly discredited until the British Association Committee found another tooth of this sabre-toothed tiger in the Long Arcade further on in the Cavern; a find of more value as reinstating the credit of MacEnery than for the interest attaching to the great carnivore itself. The party then examined the Bear's Den; a chamber which greatly puzzled MacEnery, ignorant of the fact that he was dealing with a far more ancient stalagmite than he had investigated in other parts of the cave. From the Bear's Den the visitors proceeded to the Rocky Chamber, noticing the famous "Hedges' Boss" on the way. The Rocky Chamber, investigated late in the explorations, has scarcely received the attention it deserves, as the pipe-like stalagmites springing from larger bosses seem to indicate a considerable variation in the rate of accumulation of carbonate of lime at some unknown period of the cavern's history. In considering the question of the Kent's Cavern stalagmites, it is well to bear in mind that the atmosphere being saturated, there is no evaporation; that the formation of stalagmite there is a question of a little more or less carbonic acid in the water, and a difference of a few degrees of temperature in the cave. Whether the incoming water will corrode the limestone, or deposit carbonate of lime, apparently depends on whether the lime-charged water enters an atmosphere cooler or warmer than itself. In the former case it may dissolve, in the latter deposit.

* See *Trans. Devon Assoc.*, vol. v, p. 263.



ROUGH SKETCH PLAN OF KENT'S CAVERN (*A. R. Hunt*).

A. Great Chamber.
B. Gallery.
C. Lecture Hall.
D. S.W. Chamber.
E. Water Gallery.
F. Passage of Urns.
G. Vestibule.
H. Sloping Chamber.
I. Wolf's Den.
J. Charcoal Cave.
K. Long Arcade.
L. Underhay's Gallery.
M. Clinnick's Gallery.
N. Rocky Chamber.
O. Cave of Inscriptions.
P. Hedges' Boss.
Q. Swallow Gallery.
R. Great Oven
S. Labyrinth.
T. Bear's Den.
U. Tortuous Gallery.
V. Lake & Crypt of Dates
W. North Sally Port.
X. Underground Passage.
Y. Smerdon's Passage.
Z. Inscribed Boss.

Although the plan of Kent's Cavern makes no claim to accuracy, it may be as well to mention that there is a slip in the passage to Q (the Swallow Gallery), the passage actually starting as a continuation of R (the Great Oven), instead of as a continuation of O (the Cave of Inscriptions).

The most impressive facts in the cavern are the rocky crystalline stalagmite and the spongy porous stalagmite. They seem to tell of slow climatic changes of incalculable duration. The eroded valleys tell a like story. The advent and disappearance of the hyæna, as a short episode in the cave history may give us pause; but the stalagmites cannot be regarded as indices of time-gaps. We need not expect either man or beast to inhabit by choice the wettest portions of the cavern, or to find many bones in stalagmite; but as a matter of fact bones of bears were found throughout the ancient floor, and hyæna, rhinoceros, and others in the newer floor, close up to the surface.

Nearly eighty implements and fragments were found in the breccia.* Pengelly calls them "nodule" tools, as distinguished from the cave-earth palæolithic tools, which are trimmed flakes, whereas the breccia tools are trimmed nodules. The fact is, that in Kent's Cavern we have two epochs of palæoliths, with an amount of time supposed to be represented by 12 feet of stalagmite + x years between them. There is no proof that the breccia type of tool was ever made in the cave-earth era. Of course a "cave-earth" man might find a "breccia" tool, just as we ourselves might at the present time.

Before the first party had seen the cavern, the second party was ready to enter, but unfortunately time was running very short, and their inspection was somewhat hurried.

In Anstey's Cove Mr. Ussher showed that the red and green slates as at Petitor were newer than the limestones which they seemed to underlie, and at the junction with them exhibited evidence of the presence of the liver-coloured Goniatite beds. On Redgate beach the eyes of the party were gladdened by a comparatively simple series of curves, bringing the beds at the base of the fine cliff to its crest in convolutions of different degrees of intensity; but this glimmer of simple fact was soon clouded over when it was pointed out to them that limestones of different horizons in the mass were brought together by faults at either end of the beach along the projecting cliff faces, and by faults parallel to the main cliff, crossed and shifted. There was hardly time to deal with more than five or six of these, when it was found advisable to proceed to the cavern from which the first party soon emerged.

The Rev. G. F. Whidborne led a small party to Hope's Nose, where they had the opportunity of glancing at the Raised Beach.

The members now proceeded to the Torquay Museum, and examined the fine collection of local fossils. After which they were entertained to tea by the Committee of the Torquay Natural History Society. Before parting, Mr. Whitaker, the President of the Association, proposed a hearty vote of thanks to the Torquay

* See *Trans. Devon Assoc.*, vol. xiv, p. 685.

Natural History Society for their hospitality, which was greatly appreciated, and he also returned thanks to Mr. Hunt and Mr. Ussher for their services as Directors on this and other occasions. Mr. Boase, President of the Torquay Natural History Society, and Mr. Hunt briefly replied.

In contrast to the proceedings under the guidance of Mr. Hunt, Mr. Woodward (in seconding the vote of thanks) referred to the visit paid to "Kent's Hole," in 1794, by Mr. W. G. Maton, F.L.S., who thus wrote: "Two women, whose usual business it is, conducted us to the spot, provided with candles, tinder-boxes, and other necessaries for the expedition. After pursuing rather an intricate track, we arrived at the mouth of the cavern. . . . The aperture was just large enough to admit us. . . . We began to fancy ourselves in the abode of some magician, or (as our companions were two ancient females, and not the most comely of their years) in the clutches of some mischievous old witches. . . . The roof is in some places so low we were obliged to advance on our knees."*

V.—Newton Abbot, East Ogwell, and Wolborough.

By H. B. Woodward.

On *Tuesday, April 17th*, the members started by Mill Lane and past the Bradley Manor House on the borders of the River Lemon, where in the bed of the stream the Director had found a polished stone-implement. After a pleasant walk along the wooded ravine the quarries on the north side of the valley in Broadridge Wood, and near Chircombe Bridge, where the Middle Devonian Limestones are well exposed, were visited. Crossing the bridge, and taking the path on the south side of the stream, an old limestone quarry was next visited, and then the scarp was ascended to the Pulpit Rock. Here the Limestone yields in abundance the Coral, *Favosites* (*Pachypora*) *polymorpha*. Occupying the pulpit the Director made some general remarks on the Devonian series, on the pioneering work of Godwin-Austen, and on the difficulties met with in Devonshire. Lonsdale's original observations (dating back to 1837) on the Devonian system were referred to, and it was pointed out that his suggestion of a formation intermediate between the Silurian and Carboniferous was based on a study of the fossils of the South Devon limestones. Neither the top nor the base of the Devonian system was then defined.

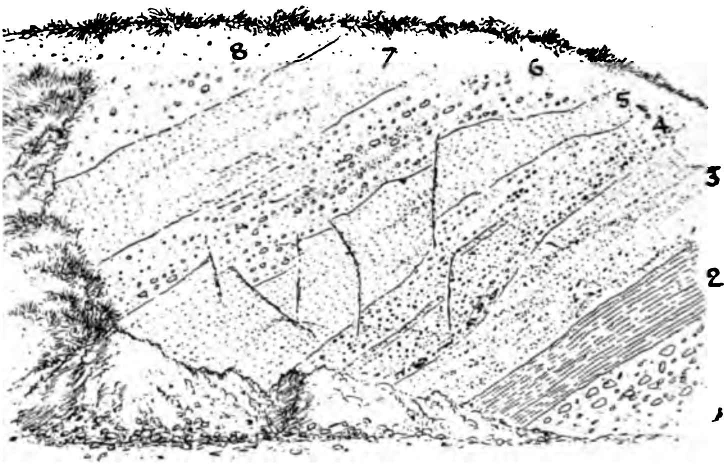
Reference was made to the subsequent work of Holl, and more especially to that of Champernowne, Mr. Ussher, and the Rev. G. F. Whidborne.

The difficulties in determining the sequence of the local Devonian rocks were very great, owing to the irregularities of the strata, and the great disturbances to which they had been subjected. The fossils, too, were more often than not crushed and badly preserved. Light, however, had been obtained by studying the

* "Observations relative chiefly to the Natural History, etc., of the Western Counties of England," 1797, p. 119.

divisions made in Germany, and by applying the zonal succession there established to the elucidation of the Devonian sequence in this country. Different stratigraphical divisions must, however, be made in this country, as abroad, where the Franco-Belgian grouping differed from that in Germany.

As Mr. Ussher had pointed out, the Middle and Upper Devonian Beds were to some extent locally represented by a mass of limestones in which no definite plane of division could be made. Thus we had the lower portions of the limestone-series at Chircombe Bridge, and an ascending series as we passed eastwards through Bradley Woods to Ramsleigh.



SECTION AT WOLBOROUGH CHURCH, NEWTON ABBOT.
(*H. B. Woodward*, 1896.)

BOVEY BEDS.	8. Gravel and sand.	4. Sand and fine gravel.
	7. Reddish sand.	3. Sand.
	6. Gravel and sand.	2. Clay.
	5. Reddish sand.	1. Coarse gravel.

Height of section about 30 feet. Length, 60 yards.

Returning along the top of West Hill the members now took the lane to East Ogwell, crossing the decomposed schalsteins and limestone, and also slates, on the way to Ramsleigh or Ransley quarry on East Hill. Here the limestone, as observed by Champernowne, represented the Frasnian stage of the Upper Devonian, and was characterised by *Rhynchonella cuboides* and *Acervularia pentagona*. Many examples of the "stromatactis," previously referred to, were noticed in this quarry. Eastwards the limestone is brought abruptly against Culm-measures, which were seen in the road-cutting. Thence the party proceeded by

Ogwell Cross to the quarry near Prospect Cottages, Wolborough, where the Middle Devonian Limestone is much stained with ferruginous matter derived from the New Red beds.

Phacops latifrons, *Bronteus flabellifer*, *Goniatites*, *Orthoceras*, *Stringocephalus burtini*, *Spirifera verneuili*, *Rhynchonella pugnus*, and *Atrypa reticularis* have been recorded from Wolborough.

The gravel pit by Wolborough Church (175 feet above sea-level) next attracted attention. Here the beds dip towards the S.E. at from 35° to 45°. The presence of coloured sands and white clays and the high inclination tended to associate the beds with those seen at Staple Hill and Aller Vale, and to support Mr. Clement Reid's contention that all were Bovey Beds.

The Director remarked that during his stay in Newton Abbot, 1874–75, he was sorely perplexed with these and other sands and gravels. Eventually he came to the conclusion that they were drifts, and that there was some connection between the plateau-gravels of Haldon and those which occurred with this high marginal dip in the Bovey Basin.[*] Now Mr. Reid had thrown light on the subject. He had traced the extension of the Bagshot Beds on to Haldon, into the very plateau gravels.[†]

On the other hand it is right to mention that Mr. A. E. Salter has regarded the deposits on Wolborough Hill and Milber Down as "Lower Level Plateau Gravels," derived in part from the Haldons.[‡]

The members now proceeded by the Newton College recreation ground to the Decoy Clay pits belonging to the Devon and Courtenay Brick, Tile, and Clay Co. Here, as pointed out long ago by J. H. Key, the beds have a considerable inclination towards the east, and both clays and thin lignites have been exposed. The clays have been worked to a depth of 90 feet in some parts, the workings extending along the strike of the highly inclined beds. Intercalated in the mass of pipe-clays are occasional layers of sand. The clay is mostly white or pale grey, but it has pink staining in places, like the coloured clays of the Bagshot Beds in Dorsetshire.

The members now returned to the Globe Hotel, and the Easter excursion of 1900 came to an end.

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[*] *Quart. Journ. Geol. Soc.*, vol. xxxii, p. 234.
[†] *Ibid.*, vol. liv, p. 235.
[‡] *Proc. Geol. Assoc.*, vol. xv, p. 282.

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FIG. 1.—BOWERMAN'S NOSE, NEAR LUSTLEIGH.
(From a Photograph by H. Preston, F.G.S.)

FIG. 2.—LIGNITE PIT, NORTH OF PRESTON, KINGSTEIGNTON.
(From a Photograph by A. K. Coomara Swamy, F.G.S.)

EXCURSION TO WIMBLEDON AND KINGSTON.

SATURDAY, APRIL 28TH, 1900.

Directors: W. WHITAKER, B.A., F.R.S. (President); H. W. MONCKTON, F.L.S., V.P.G.S.; AND W. P. D. STEBBING, F.G.S.

Excursion Secretary: PERCY EMARY, F.G.S.

(*Report by* H. W. MONCKTON.)

THE members assembled at Wimbledon Station at 2.45, and, walking to the top of the hill, were there joined by several cyclists, who throughout the day followed the leadership of Mr. Stebbing.

There have for the last few years been very few sections on Wimbledon Common; indeed I have not seen a good one since November, 1892, when some drainage works at its south end (level, 175 ft. O.D.) showed a fair section in the gravel which caps it. There is, however, a small gravel pit a little north of Cæsar's Camp, close to the figure 169 on the one-inch Survey map, New Series, and this was the first section visited. It showed some 5 feet of yellow and brown, very sandy, current-bedded gravel, composed of the same classes of material as the gravel on Kingston Hill described later on. Attention was drawn to the very flat surface of the Common, and the walking party then proceeded to cross the valley of the Beverley Brook by a footpath to Kingston Hill, the cyclists following Mr. Stebbing by a different route. We had not time to visit the small gravel pit near Warren Farm, though we saw it in the distance. I, however, have examined it on several occasions, and found the gravel to be well stratified, and similar in composition to the sheets which cap the adjoining plateau and Kingston Hill, and I have no doubt that it is formed of débris from the older gravel.

The section at Coombe Warren (referred to in the *Quart. Journ. Geol. Soc.*, vol. xlix, p. 317) is not now open, and we continued our way to the large gravel pit at the top of Kingston Hill, which has long been worked for road metal, and was last examined by the Association on June 12th, 1880 (PROCEEDINGS, vol. vi, p. 370; "Record of Excursions," p. 83).

The section is a very fine one, and shows some 20 feet of very well stratified gravel, beautifully current-bedded in many places, and often very sandy. Several large patches of sand were pointed out by the President as being evidently re-arranged Bagshot Sand. It seems to me that in the older geological history of our country we should scarcely be able to match this deposit. Apart from other differences, the presence of a large proportion of subangular stones distinguishes it from the Eocene gravels of Bournemouth, from the Oldhaven Beds, from the Bunter Beds, etc. Possibly some of the gravels in the west, classed by Mr. Clement Reid as

of Bagshot age (*Quart. Journ. Geol. Soc.*, 1896, vol. lii, p. 491), approach this deposit more nearly, and may have a similar origin. This gravel is not a solitary example; it is a good representative of a class of deposit found at many levels and over a wide area in the south-east of England.

The explanation of the peculiarities of these deposits may be that they were formed during a period of elevation, whereas most of our geological formations are the product of periods of more or less prolonged depression of the land. A chief feature of these gravels is the flat top, of which Wimbledon Common is an admirable example.

A flat usually means a water surface, and in this neighbourhood we have two flats, viz., Wimbledon Common (183 feet O.D.), and Ham Common (30 feet O.D.). In other parts of the Thames Valley there are more than two.* Now a series of flats in the form of step-terraces is a common occurrence in Norway, and I am inclined to attribute the gravel flats to the same cause as the step-terraces, viz., short periods of rapid elevation with long intervening periods of repose, the step or the flat marking the period of repose.

In soft strata like that in this part of England, rivers, during a period of repose, attain a low gradient. Thus the Thames crosses the 100 feet contour a little below Henley and the 50 feet contour above Staines. The result of elevation of the land would be that the rivers would begin to cut new and deeper channels through the soft strata over which they flow, and thus the effect of elevation would, apart from obstructions such as dams or weirs, extend far inland. On a pause in the process of elevation deposition would begin, and a result of the velocity of the current would be a tendency to deposit large material, and such is often found at the bottom of these gravels. There would then be a deposition of well stratified current-bedded gravels such as these on Kingston Hill, and eventually, as the river course attained a low gradient, the coarse gravel would be covered by brick-earths and fine sand.

The large stones are, in fact, very often at the bottom of a gravel, but not always. I have recorded (*Quart. Journ. Geol. Soc.*, vol. liv, p. 189) a sarsen in the middle of gravel on Chobham Ridges, and at Kingston we saw a reddish pebble (probably from the Bunter Pebble Beds), with a diameter of 6 inches, in the gravel 3 feet above the floor of the working, which was some height above the bottom of the gravel. The stone was 7 feet below the surface of the ground.

The fine grained deposit at the top of gravel is a very common occurrence. I have seen examples at all sorts of levels, from 600 feet above the sea at Cæsar's Camp, Aldershot, downwards.

* See *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 31, Fig. 1, and Whitaker's "Geology of London," vol. i, p. 391.

Further, it is very usual to find the lower part of a bed of gravel evenly stratified, and the upper part much more irregular with many contortions and long furrows. This I attribute to the fact that during the stages shortly following an elevation of the land water flowed rapidly, and deposited the well stratified gravel, whereas during the subsequent period of a stationary land-level changes of river-course occurred from time to time, and the river-ice of the winters made its mark.

The gravel of Kingston Hill is composed of subangular flints, both brown and black, but mostly the former; of flint pebbles, probably from Bagshot Beds of the immediate neighbourhood; of Lower Greensand fragments, which are abundant; and of a varied collection—quartzite and sandstone pebbles, many of which are probably from the Bunter Beds; small quartz pebbles, etc.

Leaving the pit, the members proceeded to the Albert Hotel, Kingston Hill, where tea was provided.

After tea, on the proposal of Captain Stiffe, a vote of thanks was given to the Directors, and the party entered Richmond Park, and, by the kind permission of the Ranger, visited the gravel pit near Thatched House Lodge. This completed the work of the afternoon, and the members dispersed, some walking through the park to Richmond.

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See also several recent papers relating to the Thames Valley by H. J. O. White, A. E. Salter, and Prof. W. M. Davis.

VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY).

Director: LAZARUS FLETCHER, M.A., F.R.S.

SATURDAY, MARCH 17TH, 1900.

THE members assembled in the Pavilion at the end of the Mineral Gallery, at 2.30 p.m. Mr. Lazarus Fletcher, M.A., F.R.S., Keeper of the Department of Minerals, drew attention to the Meteorites in the collection which have a special interest in the history of the subject, indicated their more salient characters, and explained to some extent the modes in which such characters have been produced.

EXCURSION TO HITCHIN AND ARLESEY.

SATURDAY, MAY 5TH, 1900.

Director: WILLIAM HILL, F.G.S.

Excursion Secretary: A. K. COOMARA SWAMY, F.G.S.

(*Report by* THE DIRECTOR.)

THE party arrived at Arlesey (Three Counties Station) at a little before three o'clock, and proceeded at once to the large Gault pit in Messrs. Beart and Co.'s brickyard. On the eastern side of this pit a section was seen which included the lower 10 ft. of the Chalk Marl, the thin Cambridge Greensand, and the Gault. The Cambridge Greensand was only exposed for some 12 or 15 yards, the bed having been thoroughly worked out in this district for the coprolites it contained, which in the heyday of agriculture were in great demand for making artificial manures. The few yards now seen had been preserved by an old kiln, which it did not pay to remove when the coprolites were dug.

The President pointed out that the bed was evidently a line of erosion; though the base of the Greensand was sharply marked the upper surface of the Gault on which it rested was uneven. It contained two sets of fossils, one derived from the Gault, and the other indigenous to the bed itself; the latter more closely related to the Chalk than to the Gault fauna. The bed passed up gradually to the Chalk Marl, and was regarded as the base of the Chalk. Members were able to obtain a good view of this interesting bed now so rarely seen; below it the large pit at the brickworks exposed some 50 ft. of unfossiliferous Gault.

The quarry of the Arlesey Cement Works was next visited. The upper part of the Chalk Marl, together with the Totternhoe Stone and some 10 or 15 feet of the chalk above it were exposed. The Director pointed out that the Chalk Marl was here about 70 feet thick; the bluish-grey marl seen at the base of this quarry was the upward continuation of the whiter marl above the Cambridge Greensand. There was a considerable difference in the two marls: that just above the Greensand contained only 26 per cent. of argillaceous (insoluble) matter, while the bluish-grey marl contained 46 per cent. It was seen that the bluish-grey marl passed rapidly upward into a whiter and more calcareous deposit. The aspect of the Totternhoe Stone seen in the quarry was somewhat different from that at Totternhoe. At Totternhoe there is some 30 feet of evenly grained stone, suitable for building purposes, while here the stone consists of two beds of rather rough and rugged sandy (shelly) chalk, together about 12 feet thick. The bed forms the upper limit of the Chalk Marl, and above it is the zone of *Holaster subglobosus*.

But few fossils were found in this quarry during the visit of the

Association, though in the experience of the Director it had proved exceptionally interesting from a collector's point of view.

Leaving the quarry the party took the high ground, walking along a field-way in the direction of Hitchin. From a commanding position the Director drew attention to the fact that the whole outcrop of the Cretaceous series, from Lower Greensand to Upper Chalk, was in view. The President remarked that the outcrop of the Gault in this district is some miles wide, while in Surrey that outcrop is less, and often very much less, than a mile wide, this being due to the steeper dip of the beds in Surrey.

On gaining the high road the party proceeded over Wilbury Hill towards Hitchin, crossing the old "Icknield Way" at right angles, the Director drawing attention to some facts of antiquarian interest. They then visited a small but very typical exposure of the Melbourn Rock and after a brisk walk arrived at Hitchin at 6.30 p.m.

After partaking tea the members separated, those who had not already seen the freshwater deposit at the Folly, Hitchin, joined the Director in a visit to this interesting section. It has already been described in the PROCEEDINGS,* but since the last visit of the Association Mr. Clement Reid has investigated the bed, and the results of his work are published in the *Proc. R. Soc.*, vol. lxi, p. 40 (1897), reprinted in *Trans. Herts. Nat. Hist. Soc.*, vol. x, pt. i, pp. 14-22 (1898).

Other members visited some interesting gravel pits, or spent their time in the quaint old town of Hitchin. Joining again at the station the party returned to town by the 8.24 p.m. train, having spent a most enjoyable afternoon.

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EXCURSION TO HERTINGFORDBURY, BAYFORD, AND BRICKENDEN GREEN,

SATURDAY, MAY 19TH, 1900.

Director: A. E. SALTER, B.Sc., F.G.S.

Excursion Secretary: A. K. COOMARA SWAMY, F.G.S.

(*Report by* THE DIRECTOR.)

THE party arrived at Hertingfordbury Station (G.N.R.) about 2.30 p.m., and immediately set off to visit two large pits showing gravel and clay resting upon Chalk. Owing to the presence of pipes

* Vol. xiv, pp. 415-419.

in the chalk the overlying gravel and clay were disturbed in places. The Director stated that the deposit was about 200 ft. O.D., or rather more than 50 ft. above the Lea, and consisted mainly of flint in various forms, together with a noticeable proportion of foreign material, among which were varieties of dolerite and rhyolite of uncertain origin, and many Bunter pebbles. Jurassic débris was absent or very rare. The gravel was capped by a chalky clay, probably redeposited. This deposit seemed to be derived from Eocene and older Drift beds, and was formed during the excavation of the valley between the Chalk "cuesta" to the north and the "mesa" about to be visited on the south.

More chalky clay and Glacial sands were seen on the road leading up to Bayford, and the Director drew attention to the presence of such deposits at various heights in the Lea Valley, and questioned their utility as a geological datum line.

At Bayford (300 ft. O.D.) some old workings in High-Level Drift (Westleton Shingle of Prestwich) were examined, and their contents contrasted with those seen at Hertingfordbury. Flint and quartz pebbles are plentiful; radiolarian chert, jasper, schorl rock, and other foreign pebbles occur. Similar deposits are to be seen at other places on this plateau, and many of the constituent pebbles are singularly like those found in deposits at much higher levels in Derbyshire and in the south-west of England, pointing to the former existence of much larger drainage areas than there were at present. A large dolerite boulder, obtained while sinking a well, was examined and its microscopic structure described.

Near Brickenden Green another high-level deposit was seen. It consisted mainly of flint and quartz, but a good deal of Lower Greensand chert was seen, which pointed to its having been, partially at least, derived from the south or south-west possibly before tectontic movements of considerable extent had occurred.

At Brickenden Green more dolerite boulders were seen, and on the road to Hertford some interesting sections in a deeply-cut stream course were examined.

After tea the President called for and obtained a hearty vote of thanks to the Director, and the party soon afterwards returned by train to London.

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NOTES ON THE GEOLOGY OF THE ENGLISH LAKE DISTRICT.

By J. E. MARR, M.A., F.R.S.

(Read July 6th, 1900.)

A.—INTRODUCTION.

THE Council of your Association has done me the honour of inviting me to act as Director of an excursion to Lakeland in the course of the summer. In these circumstances, as I have been engaged in studying the geology of the district for many years, and have arrived at certain conclusions which have not hitherto been published, I may be pardoned if I incorporate among notes which may serve to give some idea of the general structure of the district, a summary of such conclusions; especially as, in my opinion, a knowledge of them is requisite to a right understanding of the actual structure.

For several seasons I have had the pleasure of working in Cumbria with my colleague, Mr. Alfred Harker. Many of the facts and conclusions recorded in this paper are the result of this joint work, and my colleague shares with me the credit for any records which may be of value. I shall endeavour in the paper to point out clearly such portions as must be regarded as the joint work of Mr. Harker and myself. I have obtained his permission to give this brief preliminary outline of the results of our work, and should any errors be found therein I ask that I alone may be considered responsible for them.

It is well-known that the heart of Lakeland is composed of Lower Palæozoic rocks, and that around these is a girdle of later deposits of Carboniferous, Permian, and Triassic ages.

The sub-division of the Lower Palæozoic rocks into three great natural lithological groups was first made by Jonathan Otley, in a paper in the *Lonsdale Magazine* (vol. i, 1820, p. 433), and this tripartite grouping has been always recognised by subsequent writers, though the names applied to the groups vary in different memoirs. The following table will show the nature of the rocks:

Upper Slates (with Coniston Limestone at base), flags, grits, and slates.

Middle Slates ("Green Slates and Porphyries," "Borrodale Series"), volcanic rocks.

Lower Slates (Skiddaw Slates), dark argillaceous rocks with interbedded grits.

As regards the geographical distribution of these divisions, (leaving minor complications out of account for the moment), it may be stated that the axis of uplift of the main anticline

into which the slates are folded runs through Skiddaw in an E.N.E.-W.S.W. direction, and that the Lower Slates or Skiddaw Slates are developed to the north and south of this axis. On the north side they are succeeded by a narrow and somewhat remarkable band of the "Middle Slates" (here only styled slates for convenience) which runs from near Greystoke Park, a few miles west of Penrith, to Cockermouth. The southern boundary of the Skiddaw Slates, where they are again succeeded by the Middle Slates (or Green Slates and Porphyries), commences on the east at the north-east or lower end of Ullswater, is traceable thence to the south end of Derwentwater, thence past Buttermere and Ennerdale Lakes, and on to the neighbourhood of Egremont, on the west of the district. The junction between Middle and Upper Slates is well defined by the Coniston Limestone, which, starting near Shap, strikes across the heads of Windermere and Coniston Lakes, and then past Broughton Mills, to the south-west of Cumberland at Millom.

The actual age of most of the deposits, owing to comparative rarity of fossils, was for a long time a matter of dispute, and even at the present day the geological horizon of some of the groups of rocks can scarcely be regarded as settled.

For many years there was a general consensus of opinion as regards the general age of the three main groups above noticed. The Skiddaw Slates, on account of the nature of their included organisms, were referred to the Arenig epoch; the middle division was considered to be of the Llandeilo epoch; while the upper division was believed to have representatives of strata from Caradoc to Ludlow, both inclusive. As the result of detailed study of the fossils the correctness of the last correlation has been firmly established, but doubt has been thrown on the other two, and especially upon the second. I shall attempt to show, however, that in each case the reference is mainly correct.

The attention of the visitors to Lakeland in August next will be chiefly called to the Lower and Middle series of slates, which are well developed in the neighbourhood of Keswick, the head-quarters of the party; and it will be necessary to pay special regard to the character of these two groups. In so doing I shall assume that the reader will peruse these notes with the aid of the published maps of H.M. Geological Survey.

Keswick is situated some way north of the centre of Quarter-sheet 101 S.E. (Sheet 29, New Series), and it is over the ground represented in this quarter-sheet that most of the excursions will be conducted, though one will be largely on ground represented on the Quarter-sheet lying immediately to the east (102 S.W., Sheet 30, New Series).

N.B.—Members will find a geological map of the district facing p. 528 of the "Record of Excursions."

B.—DESCRIPTION OF LOWER PALÆOZOIC ROCKS.

I.—The Skiddaw Slates.

Distribution.—The extent of the main mass of Skiddaw Slates has already been noticed. It is important for our purpose to note, in addition, the occurrence of other outcrops. In the neighbourhood of Ullswater an isolated patch is separated from the main mass by the conglomerate of Mell Fell, to be referred to subsequently; beneath this it probably continues to join the main mass. South of the Ullswater patch is an extensive patch stretching from the hamlet of Butterwick to the vicinity of Shap.

In the Lower Palæozoic inlier of the Cross Fell range, east of Eden, is a continuous patch of these slates, stretching nearly the entire distance of that outlier. In the extreme southern extremity of Cumberland an isolated outcrop of Skiddaw Slate forms the hill known as Black Combe, and a smaller patch occurs on the opposite side of the Duddon estuary, to the north of Dalton-in-Furness. The significance of these outcrops to the south of the main mass will be eventually considered.

Lithological Characters.—There is a general sameness in the characters of the whole group, though the rocks often differ considerably in detail. Shales, slates, and grits are the dominant rocks, and detrital mica is usually abundant. Carbonate of lime is practically absent, except in mineral veins traversing the rocks. The shales vary in colour from bluish-grey, or sometimes greenish-grey, to black. In texture they may be hard and splintery, or soft and earthy. Many of them are cleaved, though they never give rise to roofing slates of such utility as those of the Middle Slates; in other places cleavage is absent, and this is especially marked in the more northerly part of the main expanse.

The grits are very variable. Some, like the "Skiddaw Grit," are coarse quartzose rocks, sometimes becoming conglomeratic; others are much finer and are often laminated. These contain varying proportions of muddy matter, and so pass gradually into the shales and slates. Many of the arenaceous beds seem to be affected by true ripple-marks, and were probably deposited in shallow water, though in other cases structures simulating ripple-marks seem to have been caused by subsequent movements.

The presence of volcanic rocks in the upper part of the Skiddaw Slates is a fact of considerable interest. Mr. Clifton Ward inserts intercalated volcanic rocks in the beds near the contact with the Middle Slates, at the Hollows Farm, near Grange, in Borrodale, and at the south-west end of Crummock Lake. Other volcanic rocks are intercalated with the higher Skiddaw Slates of the neighbourhood of Shap, and also in those of the Cross Fell inlier.

With our present knowledge, any attempt to subdivide and classify the Skiddaw Slates by reference to their lithological characters only, would be premature.

The thickness of the group was estimated by Mr. Clifton Ward as at least 10,000 or 12,000 feet. As will be seen presently, however, it is very difficult to judge of the amount of repetition which may have occurred owing to subsequent folding and faulting.

Age of the Slates: the Fossil Evidence.—The occurrence of fossils in these slates has long been known; of recent years the number of recorded species has been largely increased, owing mainly to the work of assiduous local observers, of whom special mention may be made of the late Mr. Kinsey Dover and Mr. J. Postlethwaite. To the labours of the latter gentleman we may look forward in expectation of a still further increase in the number of forms discovered. The latest discoveries confirm the earlier, and indicate that the main mass of the *fossiliferous* Skiddaw Slates is of Arenig age, though some Tremadoc forms probably occur, and possibly also some Llandeilo species. This conclusion is reached by Miss Elles, the latest student of the Skiddaw Slate fauna. The fossils, however, are by no means uniformly distributed through the slates. They are commonest in, though by no means confined to, the black slates, especially those of an earthy texture. More important is the fact that the fossiliferous bands often run in linear belts. The most marked commences in the upper part of the Glenderamakin Valley, is traceable along the ridge of Saddleback, and is possibly continued on the west side of the Derwent Valley, crossing the lower part of the Whinlatter Pass, forming the top of Grizedale Pike, and reaching Whiteside, near the foot of Crummock. On either side of these belts of fossiliferous rock lie the great grit bands, and at present there is no evidence as to the age of the latter, except that, for reasons to be given later, they can hardly be newer than the fossiliferous Skiddaw Slates, and as the latter are not likely to alter their characters so rapidly when traced across the strike, they are probably not contemporaneous with them. The probability, therefore, is that they are older, though how much older one cannot say. It is to be hoped that local observers will examine these rocks very carefully, and endeavour to find fossils in some of them.

Next to the Graptolites the Trilobites are the most abundant fossils hitherto discovered. Most of these appear to belong to the higher beds of the Skiddaw Slates, and the assemblage is essentially one which recalls that characteristic of the fauna of Dr. Hicks' Llanvirn group. In this connection it is interesting to recall the record by Mr. Kynaston of *Placoparia*, a form more frequently discovered in Central European rocks of this age, though also found at St. David's.

II.—The Green Slates and Porphyries or Volcanic Rocks of Borrodale.*

I specially wish to retain the title "Green Slates and Porphyries" for these beds, not only as really very descriptive, but because the alternative title introduces the name of a locality where the series is by no means typically developed. Mr. Harker and I recognise the following divisions among the volcanic rocks of this series, which are given in descending order:

Shap Rhyolites.
Shap Andesites.
Scawfell banded ashes and breccias=Kentmere-Coniston Slate Band.
Ullswater basic lava group=Eycott group.
Falcon Crag and Bleaberry Fell Andesites.

This division does not differ very notably except in detail from that given by Mr. Clifton Ward in his Horizontal Section, No 3, illustrating his paper "On the Physical History of the English Lake District" (*Geol. Mag.*, Dec. II, vol. vi, p. 54).

We have reasons for believing that the Yewdale breccia belongs to the series of Shap rhyolites, and is separated from the rocks on the summit of High White Stones by the Shap andesites. The divisions A, B, and C of Mr. Ward's section just mentioned, on High White Stones, we refer to the Scawfell ashes and breccias. D, E. F, and G partly correspond with the Ullswater lavas, but the main mass along the line of section consists of flinty, often streaky rocks, frequently containing felspar crystals of considerable size, and also furnishing, in many places, abundance of garnets. Of these rocks more will be said anon. Lastly group H contains the Falcon Crag and Bleaberry Fell andesites, though the lower part of the basic group may be included in it, along the line of section; the section, however, is on too small a scale to enable us to judge of this with certainty.

The following section from Derwentwater to Coniston (Fig. 1) shows the relationship of the different divisions:

DESCRIPTION OF THE MAIN CHARACTERS OF THE DIFFERENT GROUPS, AND OF THEIR GENERAL DISTRIBUTION.

(i.) *Falcon Crag and Bleaberry Fell Andesites.*—These rocks were selected by Mr. Ward as typical of the lavas and ashes, and were very fully described by him in the memoir of "The Geology of the Northern Part of the English Lake District," pp. 13-19. They form a syncline between the Valley of St. John and that in which Derwentwater is situated, and extend from the junction with

* This description of the volcanic rocks (II.) must be regarded as the joint work of Mr. Harker and myself, though I alone am responsible for the manner in which it is given.

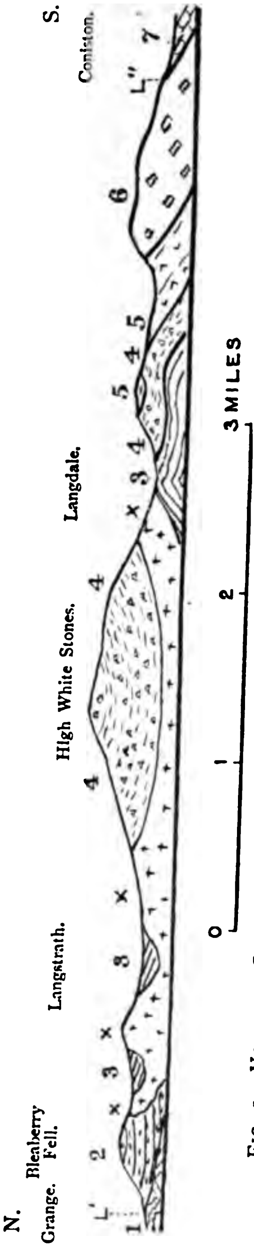

FIG. 1.—VOLCANIC SERIES FROM THE SOUTH END OF DERWENTWATER TO THE NORTH END OF CONISTON.

1. Skiddaw Slates.
2. Falcon Crag and Bleaberry Fell Group.
3. Ullswater Basic Group.
4. Scawfell Banded Ashes and Breccias.
5. Shap Andesites Group.
6. Shap Rhyolite Group.
7. Coniston Limestone.
X. Intrusive? garnet-bearing rocks.
L'. Lag-fault between Skiddaw Slates and Volcanic Rocks.
L''. Lag-fault between Volcanic Rocks and Coniston Limestone.

the Skiddaw Slates on the north to the neighbourhood of Watendlath Tarn on the south. It is doubtful whether they are represented in any other part of the district, though some of the lower rocks just above the junction with the Skiddaw Slates between Shap and Ullswater may appertain to them, for lavas from Pooley Bridge, and Crag's Mill, Shap, give silica percentages of 58·65 and 61·95 respectively. A condensed description of the rocks may also be found in a paper "On the Geology of the Neighbourhood of Keswick," written with reference to the last excursion of the Association to the district by your then President, Mr. W. H. Hudleston.*

The individual lavas, on the whole, are rather thin, and accordingly vesicular structure is particularly frequent. They are associated with ashes and breccias. (The nature of the basal purple breccia will be discussed later.) The lavas are usually of intermediate composition, with a silica percentage of 59 to 61, and a specific gravity 2·65 to 2·7, but it could hardly be expected that all the lavas should have a percentage within these limits, and as a matter of fact we find that one of the lavas in Ward's typical "Falcon Crag Section" (probably the base of his No. 5 lava), has a

* *Proc. Geol. Assoc.*, vol. vii, p. 213.

silica percentage of 54·35, thus closely approaching the normal basic lavas of the district. It is expected that further examination will furnish us with other basic rocks appertaining to the Falcon Crag division.

As regards the general characters of these intermediate lavas "they are pyroxene-andesites, the pyroxene being sometimes a rhombic one (hypersthene), sometimes a monoclinic (augite), or the two often occurring together. These minerals are not in crystals large enough to be easily detected by the eye, though the dark patches due to their decomposition-products may often be observed. Porphyritic felspars are usually present, sometimes rather crowded and up to a quarter of an inch long, but more usually scattered, and often minute. The ground mass has a very compact look, with usually either a pale greenish or dark grey tint. Many of the flows are vesicular, and the vesicles may reach considerable dimensions, as, for instance, on some parts of Grange Fells. They are commonly filled with chalcedony, agate, calcite, chloritoid substances, etc., in concentric layers.

"Some of the andesites have a special character in the occurrence of little red garnets."*

The lavas and ashes of this group are of interest on account of the slight changes which they have undergone as the result of subsequent earth movements, except towards their southern extremity. The ordinary features of volcanic rocks may accordingly be readily studied in them. Many of the lavas show marked tabular jointing, as, for instance, Ward's No. 4 on Falcon Crag, and a lava which is seen on the roadside between Lowdore and Grange. Ward records garnets in the ash intervening between his lavas 1 and 2 on Falcon Crag. They are very minute.

(ii.) *Ullswater Basic Group=Eycott Group.*—We have adopted the name Ullswater Group for this series of volcanic rocks, as they are extremely well developed among the hills around the upper part of Ullswater. They appear, however, to be the most widely distributed of all the divisions marked by presence of abundant lava flows, though the area covered by them may perhaps be exceeded by that occupied by the Scawfell ashes and their equivalent slate band to the south. The detection of this Ullswater group is a matter of considerable importance as throwing light upon a matter which has puzzled previous writers, namely, the whereabouts in the main development of the Green Slates and Porphyries of the equivalents of the well-known Eycott Hill volcanic rocks which occur on the northern side of the great Skiddaw anticline.

These Eycott rocks, which sweep round from Eycott Hill,

* HARKER, A.—"The Ancient Lavas of the English Lake District," *The Naturalist*, May, 1891. See also papers by the same author, "Chemical Notes on Lake District Rocks," *Ibid.*, February and May, 1899.

near Greystoke, on the north side of Carrock to the neighbourhood of Cockermouth, form the subject of a special memoir by Mr. Clifton Ward.* "They contain 51 to 53 per cent. of silica, and have a specific gravity of about 2·75." "Unlike most lavas of similar chemical composition they contain no olivine, but instead we find other basic minerals abundant, and particularly hypersthene; so that the rocks may be termed hypersthene-basalts."† The very striking lava occurring near the base of the group at Eycott Hill is well known. It contains large crystals of bytownite felspar, an inch or even two inches across.

We first detected the basic series of lavas and their associated fragmental rocks in the area of main development of the Green Slates and Porphyries while studying the phenomena connected with the metamorphism produced by the Shap Granite, but further study soon showed us the wide extent over which these rocks occurred. They are abundantly seen around Haweswater, where they present striking similarities to the typical lavas of Eycott Hill, and anyone studying the lavas of the Haweswater region would be at once convinced of the general identity of these with those of Eycott, even apart from chemical and microscopic study. One of these lavas of the Eycott type, with large felspar phenocrysts, from Randal Beck, Mardale, has a silica percentage of 53·45, with specific gravity 2·736. As already remarked, they are extremely well developed around Ullswater, and may be traced over Helvellyn to the Vale of St. John. In Borrodale they do not appear in great force on the east side, though the members of the Association will probably have an opportunity of seeing them at Galleny Force, at the foot of Greenup Gill (a specimen from this locality has a silica percentage 52·6, and sp. gr. 2·757). On the west side of Borrodale they appear to be developed in force, and may be traced hence over Honister Pass (where the workable slates are associated with them), and thence by the head of Ennerdale to Wastwater, where they are again developed in considerable force. On the south side of the great mass of Scawfell ashes, which occupies the central part of the district, they are developed in the narrow band of country between these ashes and the equivalent slate band which runs from near Shap to Coniston, as seen in the Section (Fig. 1).

There is considerable variation among the lavas of the group. The large porphyritic felspars, which are so prominent in some of the Eycott Hill rocks are fairly frequent, but in the greater number of lavas which contain phenocrysts, these are of a ferro-magnesian mineral and not felspar. Many of the features which are observable in the andesitic group are also noticeable here; in fact the similarity is usually so great that it would be difficult to

* "On the Lower Silurian Lavas of Eycott Hill, Cumberland," by J. Clifton Ward. *Monthly Microscopical Journal*, 1877.
† Harker, Alfred, *The Naturalist*, May, 1891.

separate the two groups from one another without having recourse to chemical analyses. A considerable number of these have been made (or, at any rate, silica percentages determined), and are recorded in the paper in *The Naturalist* to which reference has already been given.

(iii.) *Scawfell Banded Ashes and Breccias, and Kentmere-Coniston Slate Band.*—The presence of very fine and well bedded ashes is by no means characteristic of this division; indeed, we are accustomed to meet with them in every division of the Green Slates and Porphyries, and their presence in the Honister rocks has just been alluded to. The reason for separating the present division from others is the great development and preponderance of ashes therein, lavas being few in number and only locally developed. The Scawfell ashes are typically developed in the Scawfell group, and it is there that the members of the Association will have an opportunity of studying them. They practically form the watershed between the rivers flowing north and those flowing south in the heart of the district. In the east, they are first found on the spur of the High Street range which separates Haweswater from Ullswater. From High Street a tongue is sent off past Mardale to the east side of Haweswater. The main mass continues westward, forming the great mass of Fairfield, Red Screes, and the upper part of Helvellyn, whence a tongue runs to the head of Ullswater. It is cut through by the Dunmail Raise Pass, but the ashes set in on the west side of that pass, and are continued by High White Stones to the Scawfell group. Here they trend southward to the Coniston chain, being again cut through by Wrynose Pass. They form the summits of the Coniston Fells, and here send off a third tongue into the Duddon Valley.

Returning to the neighbourhood of Shap, we meet with a workable slate band in the valley of Mosedale, west of Shap Wells. This is readily traceable in a series of quarries, and runs by Long Sleddale, Kentmere, and Troutbeck, and along the fells at the heads of Windermere and Coniston Lakes to a point near the village of Torver, where it suddenly abuts against the Coniston Limestone. The ashes of this slate band appear at first sight very different from those of the Scawfell group, but we were soon convinced of their general identity, and afterwards obtained conclusive evidence on this point. The two seem to run together on Red Screes; but the most striking evidence is seen at Walney Scar, west of Coniston Lake, where the slate band and Scawfell ash group come together, and can be actually traced into one another, though a remarkably sudden change in the lithological characters of the rocks is noticeable at this place.

I shall here notice only those characters of the group which appear to be original, leaving the study of the features produced by subsequent changes for consideration in another section of the paper.

The most striking feature is the banding of the rocks, which may be studied on various scales; the marked bedded structure is often seen at a distance, as in the Scawfell group viewed from near the head of Eskdale, or in the great precipice of Helvellyn, as seen from Red Tarn. A nearer approach shows well-marked escarpments and dip-slopes on a smaller scale, due to minor divisional planes of bedding. These may be studied between Sty Head and Sprinkling Tarns. On still closer inspection, finer lines of lamination may often be observed in the ashes, which are even of microscopic minuteness in the very finest ashes. There is no doubt that extensive movement has occurred along many of these planes, but they were obviously bedding planes as originally developed.

Associated with the finer ashes (the finest of which must have been showered out as volcanic dust) are breccias of every degree of coarseness. Many of these are obviously true breccias of explosion, others as obviously are not, while in many cases it is impossible to state to what cause a breccia is due. This point will be considered later.

The composition of the ashes is variable, as might be expected from the fact that they occur above a basic group of lavas and below an intermediate group. In the Scawfell area an ash from the upper part of Eskdale has a silica percentage 63·1 and sp. gr. 2·755, while another from Hanging Knotts gave silica per cent. 56·60, sp. gr. 2·667. Of two rocks from the slate band, one from a quarry at Grasmere has a silica percentage of 61·75, and another from Tilberthwaite 61·25.

The slates of Troutbeck are associated with thin vesicular lavas, and lavas are probably intercalated with the ashes in other localities.

(iv.) *Shap Andesites.*—A description of these rocks is given in our paper on the Shap Granite. At Shap they occur in contact with the Ullswater group, as the ashes of the slate band are here faulted out, but farther west, as already stated, the ashes of this slate band come in at Mosedale. The Shap andesites are traceable as a continuous band from Shap to the neighbourhood of Torver, where they, like the beds of the slate band, abut against the Coniston Limestone, but reappear again near Broughton-in-Furness.

Outliers of this group appear on several hill-tops above the Scawfell banded ashes. They are found on the summits of Red Screes, Helvellyn, and the hills on the east and west side of Langdale.

The lavas are usually thin, and consequently vesicular. A specimen from between Wasdale Pike and Great Yarlside, west of Shap Wells, has a silica-percentage 59·95 and sp. gr. 2·736.

(v.) *Shap Rhyolites.*—These rocks are also described in our paper on the Shap Granite. They extend from Shap to near

Torver, and reappear in considerable force in the neighbourhood of Millom. No definite passage can be traced from the rhyolites which succeed the andesites and those which are associated with the Coniston Limestone and with fossiliferous ashes; but from their general resemblance, there is little doubt that there was originally a passage. Many of the rhyolites show remarkable nodular structures, which are specially well seen on Great Yarlside.

III.—The Upper Slates.

A very short account of these rocks will suffice. They are subdivided into the following groups in descending order:

Kirkby Moor Flags=Upper Ludlow.
Bannisdale Slates
Coniston Grits } Lower Ludlow.
Upper Coniston (Coldwell) Flags
Lower Coniston (Brathay) Flags=Wenlock.
Stockdale Shales=Tarannon + Llandovery.
Coniston Limestone=Ashgill + Caradoc.

The Coniston Limestone outcrop, as before stated, runs from Shap Wells to Millom. The group also appears on the east side of the Duddon Valley, in the neighbourhood of Dalton-in-Furness. The representatives of the Coniston Limestone are further found in the Cross Fell inlier. Of particular import is the occurrence of deposits of this age towards the extreme north of the district, at Dry Gill, in the Caldbeck Fells. A local unconformity occurs in the centre of the Coniston Limestone group. Evidences for this are seen in Stockdale and at High Pike Haw near Torver.

The Stockdale shales are of interest to us in this place, on account of their lithological characters. They consist of a thin deposit of soft black shales, succeeded by a thicker mass of harder beds containing massive grits.

The Brathay flags are fine-grained, as are the Coldwell beds to a great extent, while the Coniston grits are massive grits with few argillaceous seams.

The Bannisdale slates consist of finely laminated gritty shales interstratified with frequent thin grits, and the Kirkby Moor Flags are gritty flags and grits.

The Upper Slates are developed in the Lake District proper in the comparatively low ground south of the junction with the Green Slates and Porphyries. They form also the Howgill Fells on the east side of the Lune Valley, and travellers to Keswick by the London and North Western Railway will be able to judge of their general characters, as they are developed in force between the stations of Oxenholme and Tebay.

C.—CHANGES AT THE CLOSE OF LOWER PALÆOZOIC TIMES.*

(i.) *Previous Views on the Structure.*

It has long been known that the movements which gave the prevalent E.N.E.-W.S.W. strike to the Lower Palæozoic rocks of Lakeland occurred before the deposition of the Carboniferous rocks, which are unaffected by these movements, and it has long been recognised that the apparent structure of the axis of the district is that of a great anticline, of which the Skiddaw Slates occupy the centre, while the Green Slates and Porphyries rest upon them on the north and south, and the Upper Slates rest upon the Green Slates and Porphyries on the south.

It has also been long recognised that this main anticlinal fold is complicated by many minor folds and faults; for many years, however, these were not considered of sufficient importance to cause any great difference between the original succession and that which at present exists.

As the result of the detailed mapping of the members of H.M. Geological Survey, and especially of the late Mr. Clifton Ward, it became apparent that the junction between the Skiddaw Slates and the Green Slates and Porphyries was not a normal one, and three explanations have been hitherto suggested to account for the appearances presented at this junction.

1. Mr. Dakyns, in a short paper in the *Geological Magazine* (Decade I, vol. vi, 1869, p. 56), gives reasons for supposing that the junction is an uncomformable one.

2. Mr. Ward represents the junction as a faulted one. The faults are represented in his sections with fissures approaching the vertical, and over a considerable distance along the line of junction, that junction is represented as one consisting of two sets of faults, one of which is nearly at right angles to the other. As Mr. Ward remarks in the memoir on the Keswick Quarter-sheet (p. 48), "The boundary, in fact, appears to be formed by the constant meeting of faults having a more or less north and south direction with others having a more or less east and west course, the two frequently meeting at right angles with each other, and letting down the rocks between them."

3. Some years since, the junction was freely spoken of among geologists more or less acquainted with the district, as being probably of the nature of an overthrust-plane. I believe this opinion has received its expression in print, but am unable, at the moment, to find the reference. As no evidence was adduced in support of it, the matter is unimportant.

At the time when the first two views were put forward, the study of the effects of earth-movement was by no means in so

* Section C is a record of work carried out by Mr. Harker and myself. As before, I am responsible for the mode of expression.

advanced a state as at present, and in particular, the existence of reversed faults was supposed to be extremely rare, while faults with a fissure approaching the horizontal were practically ignored. In these circumstances the nature of the junction between the Skiddaw Slates and the Green Slates and Porphyries was of necessity a puzzle, and it is not surprising that Messrs. Dakyns and Ward should have offered these explanations. It gives me much pleasure to bear testimony to the accuracy with which the main facts were noted by these writers. Both evidently saw difficulties in explaining the actual facts, as they observed them, in accordance with opinions which were then current, but they nevertheless did faithfully record these facts, and accordingly gave most important help to subsequent workers. While on this subject I would also bear witness to the extreme accuracy of Mr. W. T. Aveline's maps of the southern part of the district. The views which we put forward would not have been arrived at so soon, if at all, had it not been for our study of the published maps of the Geological Survey, and we feel it only right to express an acknowledgment of the assistance which we have received from these maps, and their accompanying sections and memoirs.

(ii.) *General Statement of our Views.*

(*a*) It is our opinion that the present succession of the rocks in the district is, on the whole, the original one; that the Skiddaw Slates are succeeded in order by the Green Slates and Porphyries, and these by the Upper Slates. We find no evidence that the Green Slates and Porphyries are older that the Skiddaw Slates, and have been thrust over them along a thrust-plane.

(*b*) We consider that the folding and faulting which have affected the Lower Palæozoic rocks of the district are primarily due to the pushing forward of the rocks in a general northerly direction by a force acting from the south.

(*c*) Further, that the rocks moved forward at unequal rates, and that, so far as the main mass of rocks now exposed is concerned, the Skiddaw Slates moved farthest forward, causing the Green Slates and Porphyries to lag behind, and the Upper Slates in turn to lag behind the Green Slates and Porphyries.

(*d*) As the result of the lagging, we believe that a fault, whose fissure approaches the horizontal, was formed between the Skiddaw Slates and the Green Slates and Porphyries, and a similar fissure between these volcanic rocks and the Upper Slates. These fissures, it will be noticed, would have an outcrop similar to those of thrust-planes or over-faults which approached the horizontal; but they would differ from these, inasmuch as no inversion on a large scale would accompany them. We shall speak of them here as "lag" faults.

(*e*) The slices of rock defined by these great strike-faults would be affected by minor folds and faults, which would often abut against the great strike-faults.

(*f*) We consider that the evidence further shows that each of these great slices moved forward with different velocity in different parts. Thus, if the right hand portion of a rock-slice moved forward more rapidly than the left hand portion, and the rock would not stretch, it would be fractured, and the right hand portion would be pushed nearly horizontally past the left hand portion along a vertical or nearly vertical line of fracture. These faults would be dip-faults, but the displacement would be backward and forward, and not an upward and downward one. We have been accustomed to speak of these faults as "tears," and for convenience may use the term here, for the rocks are torn from one another. These "tears" correspond in some respects with the minor thrusts occurring between the main thrust-planes in a district which has been affected by overthrusting.

(*g*) Owing to these movements the rocks of the district would be broken up into rectangular or rhomboidal blocks, in each of which two sides would be defined by strike-faults and the other two by dip-faults.

(*h*) If this general thrusting in a northerly direction took place, we should find signs of overthrusting somewhere to the north, for the rocks travelling onward must have travelled over some other rocks. There seems no evidence of the extensive outcrop of the overthrust in the Lake District proper, but evidence points to the possibility of the Drygill Shales being beneath the great overthrust, and to the same thrust being the plane of separation between the Skiddaw Slates and the Upper Slates of the Cross Fell inlier.

(*i*) Such movement should be marked by many minor mechanical changes, and possibly also by chemical changes in the rocks of the district. We propose to offer evidence of the occurrence of these changes in a very considerable degree.

(iii.) *General Evidence for the Faults.*

(*a*) *The Overthrust.*—Owing to the paucity of sections, little evidence can be brought forward in favour of the actual existence of the overthrust (which must occur somewhere, assuming that our views are correct) in the present district. The position of the Drygill Shales is so extraordinary that the late Professor Nicholson and I were reluctant to place the beds in the position to which they seemed to belong after study of their fossils, but further study convinced me that these beds were really of the age of the Coniston Limestone, and Miss Wood and Miss Elles eventually proved beyond doubt that this was the case. These shales occur on the north side of the Carrock Fell igneous rocks, and to the north of them are rocks of the Eycott group. Their existence in this position is best explained, on the supposition that they occur beneath an overthrust, and in confirmation of this, I may point out that they approach rather to the Scotch type of deposit than to that which characterises the main line of outcrop of the Coniston

Limestone group. The beds have undoubtedly been affected by other changes, including intrusion of igneous rock, which may have carried them to their present elevation.

In the Cross Fell inlier, the junction between the Skiddaw Slates on the east and the Upper Slates on the west is mapped as a faulted one. Here again, subsequent changes have occurred as the result of post-Carboniferous movements, but several facts point to the existence of the Skiddaws above the Upper Slates. The Skiddaws occupy higher ground than the Upper Slates, and the apices of V-shaped outcrops of the fault point up-valley in Scordale and Pusgill. Again, the eastern slopes of Dufton Pike and Knock Pike suggest denudation along a fault plane sloping eastward. Finally, the Upper Slates here are again suggestive of the Scotch type of deposit.

I would suggest that local observers should make a very minute search for fossils in the ground lying north of Skiddaw and in the region around Cockermouth, in hopes of finding further developments of the Drygill Shales, or of other deposits appertaining to the Upper Slates.

(*b*) *The "Lag" Faults.*—As already stated, we consider that the most important of these faults separate the Skiddaw Slates from the Middle Slates, and the latter from the Upper Slates. These may be considered in order, commencing with that between the Lower and Middle Slates.

It is hardly necessary at the present day to insist on the fact that the outcrop of the junction-line between the Skiddaw Slates and the volcanic rocks which now overlie them is that of a fault with a fissure slightly inclined to the horizon, if it be not that of a conformable or uncomformable junction. The absence of conformity is generally conceded, and need not be further considered. The absence of an unconformity is not so clearly discernible at the outset, but the fact that the planes of separation of the different members of the overlying rocks frequently abut against the plane of junction of the two groups negatives the occurrence of an unconformity, and detailed examination of the junction shows an absence of nearly all the accompaniments of an uncomformity, and the presence, on the contrary, of those of a fault. It is, therefore, admitted on all hands that the junction is a faulted one at nearly every point.

The next thing to consider is the inclination of the fault. Here again little need be said. Inspection of the junction on the two quarter-sheets to which reference was made at the outset shows that the line of junction is a zigzag one. The apices of the V's in the valleys point up valley, and those on the adjoining hill-ridges in the opposite direction. The constant occurrence of this proves at once that we are not dealing with two sets of faults with highly inclined fissures, but with one gently sloping fault, for the coincidences of intersection of fault with valley-

bottom or ridge-summit are far too numerous to permit of the former explanation. Again, we sometimes find isolated masses of Skiddaw Slates projecting through the volcanic rocks, as near Scarf Gap Pass, Buttermere, or isolated patches of faulted volcanic rock resting on Skiddaws, as on the north side of Ullswater.

The fault, then, is one of gentle inclination; it remains to be seen whether it is an overthrust or a "lag" fault. If the former, the volcanic rocks must be older than the Skiddaw Slates, if the latter, they must be newer.

We believe that the view that inversion may occur here partly arose as the result of a striking resemblance between the lithological characters of the flinty ashes of the centre of the district and certain Pre-Cambrian, or supposed Pre-Cambrian, flinty ashes in other areas. We hope, however, to show that these ashes owe their present condition to subsequent changes, and we can certainly show, in the case of the rocks which occur in Borrodale, immediately north of the alluvial flat of Rosthwaite, that similar flinty ashes, developed on a small scale, are intercalated with lavas which bear a striking resemblance to Arenig lavas in other districts, so that the argument as to age derived from the flinty ashes is directly opposed to that derived from an examination of the Falcon Crag Series.

Again, there is evidence of the setting in of volcanic activity at the end of Skiddaw Slate times, of the existence of sediments of Skiddaw Slate type near the base of the volcanic rocks, and of the continuation of volcanic activity after the commencement of the Coniston Limestone period. Attention has been called to the intercalated volcanic rocks in the Skiddaw Slates, and it remains to be stated that sediments of Skiddaw Slate character are intercalated with the lower ashes of the Falcon Crag Series on the left bank of Cat Gill, which descends from near Falcon Crag. The volcanic rocks associated with the Coniston Limestone Series are seen between Shap and Kentmere, and in the Sedbergh district.

Furthermore, the volcanic accumulations in the Skiddaw slates conform very closely in character with the lowest known rocks of the actual Green Slates and Porphyries, being andesitic, while the volcanic outpourings amongst the Coniston Limestone group are similar to those of the top of the Green Slates and Porphyries, being rhyolitic.

In one place, and one place only, there seems to be a passage between the Skiddaw Slates and the volcanic series. Above the Hollows Farm, near Grange, in Borrodale, green shaly Skiddaw Slates, with much detrital mica, in which Mr. Harker found a *Lingula*, are immediately succeeded by a massive ash of the main volcanic series. The junction seems to be perfectly conformable, and specimens may actually be detached with samples of the two rocks soldered together. It seems inconceivable that this

junction should be faulted, and we believe that the rocks are here in their true sequence, and that the main "lag" fault has here left the junction between Skiddaws and volcanics, and locally shifted to a lower or a higher horizon, or, more probably, has split, giving rise to a lenticular inclusion.

Proceeding now to the "lag" fault, which separates the Coniston Limestone group from the underlying Green Slates and Porphyries, we find some differences between it and that which has just been described, and the appearances in this case are at first even more suggestive of unconformity than in the case of the more northerly fault, especially as an unconformity does exist, as already observed, in the middle of the Coniston Limestone group. The fault plane is more highly inclined than that separating Skiddaws from volcanics, and accordingly the zigzag outcrop is replaced by a straighter line. Again, though the Coniston Limestone group rests on different members of the volcanic series, as detected by Messrs. Aveline and De Rance to the west of Coniston Lake, we do not find different members of the Upper Slates abutting against the "lag" fault in so marked a manner as in the case of the northern fault. Nevertheless, detailed study of the phenomena has convinced us that we are here dealing with a true case of faulting, and not with an unconformable junction.

In some places the two "lag" faults come together, and the Coniston Limestone then rests upon the Skiddaw Slates, as seen in one or two places in the neighbourhood of Dalton-in-Furness.

Of the minor "lags," the most interesting to us at present is that which occurs beneath the Coniston Grits, for it is this which gives one a clue as to the nature of some of the most striking "tear" faults. These "tear" faults we may now consider.

(*c*) *The "tear" faults.*—If a yielding mass of strata is intercalated between two more rigid masses, and separated from them by lag-faults, portions of it, owing to differential movement, may have their planes of stratification inclined at a higher angle than that of the fault-planes. If a fracture takes place parallel or nearly parallel to the direction of dip of the strata, and movement of the yielding strata occurs at a different rate on either side of this fracture, any particular stratum will suffer lateral displacement, which will be readily detected in the case of an anticline or syncline, but which will present appearances similar to those accompanying vertical displacement along a normal fault in the case of strata dipping uniformly in one direction. That such movement has occurred in our district is shown by the nature of the displacement of a syncline in the Kirkby Moor Flags north of Whiteside Pike, between Long Sleddale and Bannisdale. A little consideration will show that the three great faults which affect the Coniston Limestone in Troutbeck, to the west of Windermere, and at the head of Coniston are of this nature. The displacement of the Coniston Limestone, which is inclined at a

fairly high angle to the south, is very noticeable. In the case of the fault west of Windermere the lateral displacement as measured upon the ground is about a mile, and yet the lower surface of the Coniston Grits, only half a mile south of the outcrop of limestone to the west of the fault, is undisturbed by it. This is inconceivable upon the supposition that the fault is normal, but is fully explicable on the view that the fault is a "tear," and suddenly ceases upward where the "lag" occurs at the base of the Coniston Grits. It follows, of course, that whereas the width of outcrop of

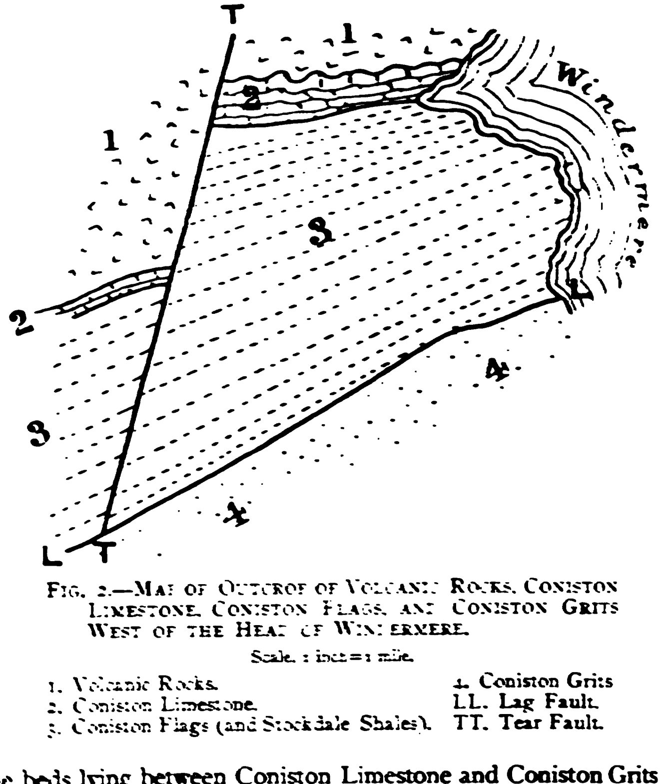

FIG. 2.—MAP OF OUTCROP OF VOLCANIC ROCKS, CONISTON LIMESTONE, CONISTON FLAGS, AND CONISTON GRITS WEST OF THE HEAD OF WINDERMERE.

Scale, 1 inch = 1 mile.

1. Volcanic Rocks. 4. Coniston Grits
2. Coniston Limestone. LL. Lag Fault.
3. Coniston Flags (and Stockdale Shales). TT. Tear Fault.

the beds lying between Coniston Limestone and Coniston Grits is about 1½ miles on the east side of the fault, it is only about ½ mile on the west side (see Fig. 2). Such a change could not be produced by mere compression, and there is no doubt that the upper part of the Coniston Flags has been carried away on the east side, and placed elsewhere. If this view as to the nature of these cross-faults be true, it must frequently happen that masses of strata are missing in some parts of the district, and reduplicated elsewhere, and this is shown to be the case as the result of

observation. The Falcon Crag group is apparently removed above the lag fault on the north side of the Green Slates and Porphyries, both in the Helvellyn range and to the west of Borrodale, and the line where the disappearance occurs seems in each case to be a "tear" fault, in one case occupying the Vale of St. John, in the other Borrodale.

The lower division of the Stockdale Shales is frequently removed in such a way that the upper division comes against the Coniston Limestone, but reduplication of these beds occurs extensively to the south-west of Coniston Lake. Again the comparatively yielding Bannisdale Slates, between the more rigid Coniston Grits below and Kirkby Moor Flags above, are frequently reduplicated in the county to the east of Windermere.

In the case of the "tears" which affect the Coniston Limestone between Kentmere and Coniston, it is noticeable that they cut through the lag-fault at the base of the Coniston Limestone, and are accordingly subsequent to it. Their upper limit is that of the lag-fault at the base of the Coniston Grit, as already stated. Their lower limit is not so clear, but probably coincides generally with a lag-fault along the great slate-band running from Mosedale to Coniston.

It need hardly be stated that the above structure is complicated by the occurrence of numerous minor lags and tears; attention has been called to some of the more striking in order to show the general nature of the movements which have affected the rocks.

(*d*) If this be the correct interpretation of the structure of the district, it follows that the volcanic rocks, which lagged behind the Skiddaws, must have accumulated in force to the southward, and that considerable duplication of volcanic rocks occurred in the centre of the district. This is fully borne out by the study of the banded ashes in the centre of the district. They appear enormously thick when compared with the equivalent beds in the slate-band to the south, but study in the field shows that there was great piling up of the ashes in the Scawfell region. The major divisional planes when viewed from a distance are seen to be at very low angles, and form a syncline whose centre lies between Bowfell and Scawfell Pike. When regarded more closely the minor divisional planes are seen to run obliquely to these larger planes, and, as will be described more fully in the sequel, still smaller planes run obliquely to those of intermediate size. In fact we are dealing with a case of pseudostromatism on a large scale. The volcanic rocks also seem to have been collected from east and west to form a huge node-like mass in what is now the centre of the district, hence the small thickness of these volcanic rocks in the Cross Fell inlier, and in the neighbourhood of Millom.

The same thing occurred with the Upper Slates, but as these are more yielding rocks resting on less yielding, instead of less

yielding on more yielding, which is the case with the Volcanics resting on Skiddaws, the great lag-plane was bent sharply downward, with a dip to the south owing to the existence of the buttress of unyielding rock to the north. Here again, the rocks seem to have been collected from east and west also.

The general structure which the Lower Palæozoic Rocks of the district would possess, in accordance with the above views, is represented in Fig. 3.

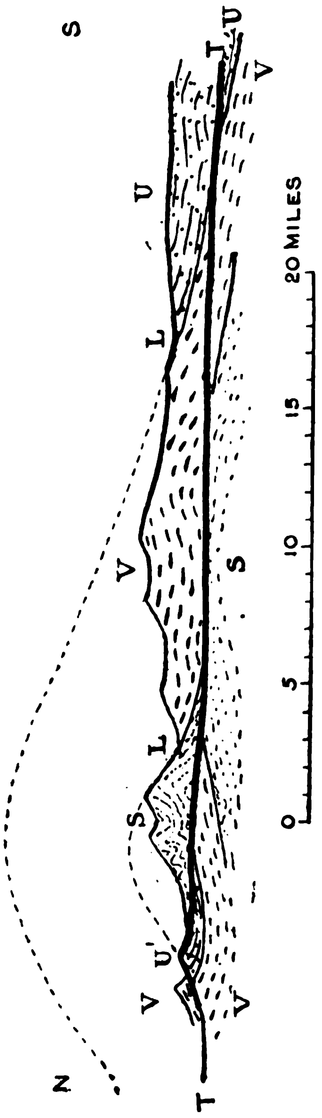

FIG. 3.

S. Skiddaw Slates.
V. Volcanic Series.
U. Upper Slates.
U'. Upper Slates below Thrust Plane at Drygill.
TT. Thrust Plane.
LL. Lag Planes.

For clearness sake, the amount of thrust has been represented as much less than the probable actual amount.

(iv.) Minor Changes in the Rocks, which are due to Movement.

As might naturally be expected, the rocks have been subjected to such changes as are the result of compression in places and stretching in others. Before considering in detail the changes which have occurred in the rocks of each division, attention may be called to the existence of slaty cleavage in all the rocks which are capable of exhibiting it, from Skiddaw Slates to Ludlow. The Lower Coniston Flags are extremely well cleaved, and the Bannisdale Slates are sufficiently so to be worked locally for slates. There seems little doubt, from this and other

structures presented by the Upper Slates, that the movement was not merely post-Ordovician but also post-Silurian, and that, in fact, it occurred during Devonian times.

We have not devoted very much attention to the changes which have occurred in the Skiddaw Slates. Beyond abundant signs of minor puckering, we get evidence of extensive stretching, as indicated by the abundance of quartz-veins which have filled fissures in many places. Slickensiding is frequent, and is often seen parallel with the bedding, and running horizontally along joint-planes: this is well exhibited in the neighbourhood of Scale Force, Buttermere. Imitation of ripple-marking, and even of organisms, is often produced by puckering and pinching of thin grit-bands between argillaceous strata. A considerable amount of chemical change has probably occurred, as the result of movement, including the frequent production of sericitic films along the divisional planes.

It is among the Green Slates and Porphyries that we find the most interesting minor structures due to earth-movement, some of which may be briefly noticed.

In the first place, when yielding vesicular lavas and ashes occur in close proximity, the ashes are often involved with the lavas in a most perplexing manner. Occasionally definite folds may be detected, but often the ashes occur among the lavas in the form of curved and curled wisps. We believe that it is owing to this occurrence that some previous observers have been led to refer to many of the vesicular lavas as ashes. An admirable instance of this complexity may be seen on the roadside in Borrodale, a short distance to the north of the Rosthwaite alluvial flat, while equally good cases occur among the Troutbeck slate quarries and by the side of Church Beck, Coniston—to mention a few out of many.

Reference has already been made to the difficulty of distinguishing original explosion breccias from those due to subsequent movement. That a great proportion of the breccias in the district are original explosion breccias may be regarded as certain, and others may be caused by the breaking up of the cooled surfaces of lava flows, and incorporation of the fragments in the still fluid mass. There is no doubt, however, that many are due to subsequent movement, and some of the evidence for this statement must now be given.

Many of the breccias occur in bands where there is other evidence of the existence of lag-planes, and a number of these are stained purple. Among these is the great breccia at the base of the Falcon Crag series, whose cataclastic origin we strongly suspect though the proofs are at present not convincing.

On High White Stones is a breccia containing fragments of flinty ash embedded in a finer matrix. The fragments exactly resemble the Scawfell flinty ashes, and as there is no doubt that

the production of the flinty structure occurred after their formation, it is improbable that original breccias should have their fragments of this character.

Far more convincing, however, are the numerous cases, among the flinty ashes, where every gradation can be traced from folding to brecciation, or from dislocation of fragments along dominant joints to brecciation. These may be studied everywhere among the ashes of the Scawfell group, and I hope to be able to show the members of the Association excellent examples on the slope between Sty Head and Sprinkling Tarns.

In several cases the brecciation has gone a stage further, and cataclastic conglomerates have been formed. They are best developed among rocks where the brecciation is due to dislocation along dominant joints. Every gradation may be traced, from ordinary rock with cuboidal joints, through brecciated rock, to a rock in which the angles are being gradually worn away, and finally into a rock where the fragments are completely rounded. I am not aware of any good cases of this in the immediate neighbourhood of Keswick, and the most striking case we have found occurs in a garnetiferous rock on the fell between Haweswater and Swindale.

Occasionally the cleavage planes are bent into sharp zigzags, as shown in some of the porphyritic lavas in the county at the foot of Haweswater.

When objects of different consistency to the matrix are found they are frequently crushed nearly flat, and this crushing is probably accompanied in all cases by a certain amount of chemical change. In the rocks just alluded to, near the foot of Haweswater, the cleavage planes are covered with micaceous or chloritic films, the porphyritic felspars are crushed flat, and have no doubt undergone chemical change in addition. The amygdules of the amygdaloidal lavas are often crushed in the same way, and sometimes curved or even contorted after crushing. This may be seen in the rocks of the section near the foot of the Rosthwaite alluvial plain. The garnets of many of the less resisting rocks break across, whereas in firmer rocks they may be extracted entire. In several rocks the garnets are converted into chlorite, and sometimes into white mica, though we are not able to assert definitely that this is a dynamo-metamorphic change. Even large fragments of breccia are flattened in the same way as the felspars, as shown in the more intensely squeezed breccias of Quay Foot Quarry, in Borrodale, where every gradation may be traced. Here again chloritic films are developed along the surfaces of the fragments.

We have notes of many other minor changes which have been produced as the result of earth movement in these volcanic rocks, but the samples given will serve to show the intensity of the forces which have affected these rocks, though we may

mention that the Armboth dyke has been affected by tear-faults, and that we have discovered a narrow dyke near Walney Scar which has been profoundly contorted.

Many of the features we have noticed, and others also, may be studied among the laminated grits and mudstones which form the Bannisdale Slates around Windermere, and afford additional evidence that the movements which produced them were of post-Ludlow age.

D.—THE LATER ROCKS.

Little will be seen of the later rocks by those who take part in the excursion, and only a few words are required concerning them.

At the base of the Carboniferous rocks is the well-known conglomerate, which is well developed around Shap, and at the foot of Ullswater. It seems to have been deposited in hollows in the older rocks, probably in old valleys. It used to be referred to the Old Red Sandstone, but is now usually included among the Carboniferous strata. I doubt the necessity for the change. In the Cross Fell inlier very low beds of the Carboniferous series are undoubtedly developed, and a quartz-conglomerate at the base of these rests on the polygenetic conglomerate to which we are alluding. I think it probable that a considerable change took place between the formation of the two conglomerates, and that the conglomerate with quartz pebbles forms the true base of the Carboniferous, while the red polygenetic conglomerate is of Old Red Sandstone age.

The character of the pebbles is of interest, as was noted by Otley. In the first edition of his Guide Book, published in 1823, he refers to the conglomerate. In the second edition (1825) he adds that the pebbles "must have been transported from some distance, as the majority do not correspond with those of the immediate neighbourhood." In the sixth edition (1837) this statement is expanded, and he remarks that they "must have been transported from some distance, apparently from the greywacké division [*i.e.* the Upper Slates], lying at some distance to the southward." The fact is that many of the pebbles are of Silurian age, and in the Cross Fell inlier, fossils (probably of Ludlow age) have been found in them, though I believe that the pebbles came from the north, for Prof. Hughes has detected fragments of Keisley limestone in these conglomerates, in the Sedbergh district. These conglomerates may be seen at the foot of Ullswater.

The Carboniferous rocks, as well known, form a broken ring round the district. The limestones may be seen from the train when travelling from Penrith to Keswick, and are here dipping gently to the east.

Permian and Triassic rocks occur in the Eden Valley and on the west coast of Cumberland, and an outlier of Rhætic beds has been discovered to the west of Carlisle.

E.—INTRUSIVE IGNEOUS ROCKS, AND THEIR METAMORPHIC EFFECTS.

A large number of masses of intrusive rock of considerable size occur in this district, and are accompanied by many minor dykes, sills, and laccolitic masses. Very little has been ascertained concerning the ages of most of them, and it will be convenient therefore to consider them according to the age of the beds into which they have been forced, as this order, being purely artificial, introduces no theoretical considerations.

Skiddaw Granite.—This is the lowest of the extensive masses of igneous rock, the exposed parts being intrusive in the Skiddaw Slates. It occurs in three exposures, which are doubtless connected beneath the surface. The generally horizontal surface suggests a laccolitic character for the intrusion, though the southern exposure, in Sinen Gill, is probably a tongue from the main mass. The normal granite "is essentially a biotite granite, consisting of orthoclase, oligoclase, quartz, and brown mica. . . . In addition to the magnesian mica there are often scattered flakes of muscovite, which are always subordinate, and not constant enough to be regarded as an essential constituent." Mr. Harker has shown that in the northern exposure, where Grainsgill joins the Caldew Valley, the granite gradually passes into greisen, with felspar subordinate or wanting, and plentiful white mica. He gives reasons for supposing that this modification is due to the greisen having been forced northward "from the partially consolidated Skiddaw granite." This is suggestive as possibly throwing some light on the age of the intrusion. We have seen that the Devonian movement which produced the great changes in the Lower Palæozoic rocks of the district was from south to north, and it seems probable that this granite was injected into the rocks during the occurrence of these movements, in which case the rock would be of Devonian age.

I hope that the members or the Association may be able to view the upper junction of the normal granite with the Skiddaw Slates at Sinen Gill; it will be then seen that the sedimentary rocks were cleaved before the intrusion of the granite, which would suggest a late age in the period of movement for the period of intrusion.

Evidence will be given that some of the other laccolitic intrusions have been forced along lag-planes. It is possible that the Skiddaw granite was forced along the great thrust-plane which we have discussed, It is not far distant from the outcrop of the

Drygill shales, which, as before observed, may be situated below the thrust.

The metamorphism of the Skiddaw Slates by the Skiddaw granite has been described by Mr. Clifton Ward in the Survey Memoir, and by Prof. Rosenbusch in "Die Stiegerschiefer." An outer zone of chiastolite slate passes into a central one, where the rock is marked by an abundance of spots composed of andalusite mixed with flakes of mica ; close to the granite this spotted rock passes into a mica-schist. These changes may be studied in the Glenderaterra valley on the way to Sinen Gill.

The changes produced by the granite have only been generally studied, and detailed examination of the slates will probably result in the detection of numerous minor variations in the character of the metamorphism. Mr. Harker has recorded the occurrence of cordierite in the Skiddaw Slates of the Caldew Valley, south-west of the farm of Swineside.

Carrock Fell Intrusive Rocks.—The rocks of Carrock Fell and the surrounding tract of country form an igneous complex, which has been very fully described by Mr. Harker. The rocks in their order of consolidation are (i) Gabbro, (ii) Granophyre, (iii) Diabase, (iv) certain basic and sub-basic dykes and veins, often variolitic. All of these rocks are probably of the same general geological age, and may be the result of differentiation of one magma. The gabbro has itself undergone a process of differentiation, for quartz gabbro occurs in the centre of the mass, while on either side of this is a normal rock, composed of triclinic felspar and monoclinic pyroxene, and, on the outer margins, these two minerals are associated with abundance of iron-ores.

The granophyre consists of a granophyric intergrowth of quartz and felspar, and of augite crystals. The granophyric structure varies considerably in different parts of the rock. As the granophyre was consolidated subsequently to the gabbro, it is found that dykes and veins of the former penetrate the latter. A remarkable modification at the junction is explicable on the view that the granophyre melted the original margin of the gabbro, and as a result a narrow band of very coarsely crystalline rock separates the gabbro from the granophyre in places. It is well shown in Farthergill Sike, above Stone Ends Farm, and it is to be noticed that the most basic modification of the gabbro has been thus affected by the acid rock.

The diabase and the basic dykes do not call for special notice in this place, and the metamorphic effects of the igneous rocks, though not traceable to a great distance from those rocks, are of too intricate a character to discuss here ; suffice it to state that when the gabbro has broken into rocks of the Eycott volcanic series, not only are the latter altered, but they have caused marginal modifications in the composition of the gabbro.

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The Carrock Fell rocks appear to be faulted to the north and

south, and as there are no exposures at the east end, and indifferent ones at the west end, the nature of the intrusions is doubtful. The manner in which the Eycott rocks are penetrated by the igneous rocks, and have furthermore been buoyed up by them, suggests, however, that we are here also dealing with a laccolitic mass, and as this mass is in close proximity to the Drygill beds, the suggestion made in the case of the Skiddaw granite is applicable here also.

The age of the rock cannot be definitely fixed, but there are certain points in the petrographical structures of the rocks, and in the physical structure of the surrounding district, which suggest a more modern date than that which was tentatively assigned to the Skiddaw granite.

The Microgranite of the Vale of St. John.—This rock occurs in two patches, one on either side of the Vale of St. John, with Skiddaw Slates between them. They have been forced along the lag-plane separating the Skiddaw Slates from the Green Slates and Porphyries. They were almost certainly once continuous, the intervening portion having been removed by denudation, and appear to form parts of a laccolitic mass, dipping gently to the north, *i.e.*, in the direction of the fault-plane. The grey compact "ground-mass consists of a finely granular aggregate of quartz and felspar, the latter predominating." Flakes of biotite are present, and small porphyritic crystals of plagioclase felspar. The rock has suffered decomposition to some extent.

Granophyre of Buttermere and Ennerdale.—The rock consists of a granophyric intergrowth of quartz, orthoclase and plagioclase felspars. The ferro-magnesian constituent is usually altered into a chloritic mineral, and epidote is also very abundant in many parts of the rock.

This and the Eskdale granite occupy a much greater superficial area than any other intrusive rocks in the district, the length of the exposure of Ennerdale granophyre being about nine miles from north to south; this is slightly exceeded by the Eskdale granite, which occupies a distance of about ten miles from north to south (or of fourteen miles, if the patch at the head of Wastwater is connected at the surface with that at the foot.)

The Ennerdale granophyre is evidently a laccolitic mass which has been on the whole forced along the lag-plane between the Skiddaw Slates and the volcanic rocks, though portions of it occur in the Skiddaw Slates, and other portions are apparently situated entirely in the volcanic beds.

There are two laccolitic masses, connected by a dyke-like band which is seen on Little Dodd, about two miles west of Buttermere lake. The lower mass of the laccolite, is about three miles long, and extends from Gale Fell to the shores of Buttermere, an isolated patch being also developed a little farther to the south on the south-west shore of the lake. The junction with the

Skiddaw Slates below may be seen in many places in the neighbourhood of Scale Force, and it is clearly seen to follow the bedding-planes of the strata. A number of tongues of the granophyre project into the Skiddaw Slate at the lower surface, and form subsidiary sills. The upper margin of the lower mass of the laccolite is also pierced by Skiddaw Slates, except at one spot, close to the summit of Red Pike, where it is in contact with the volcanic rocks. The width of this portion is about a mile in the widest part. Though it runs nearly from east to west, it is seen in the field to be sloping towards the S.E., as its eastern extremity is at a much lower level than the western. The remaining part of the laccolite is of much greater size. The lower surface extends from Floutern Tarn to the neighbourhood of Ennerdale Lake, and rests on the Skiddaw Slates, while the upper surface is capped by the volcanic rocks which form the hills between Buttermere and Wastwater. It is interrupted by two bands of volcanic rock north of Kidbeck, near the foot of Wastwater, where denudation has not been sufficient to lay bare the upper surface of the igneous rock.

The existence of more basic patches in the main rock, and of dykes and sills of a more acid or more basic composition in its neighbourhood, suggests the former existence of a magma which underwent differentiation in a manner somewhat similar to that which has been described in the case of the Shap granite. Some of these are well shown below Burtness Comb, Buttermere. The task of connecting the minor intrusions with the Ennerdale granophyre and Eskdale granite respectively will probably be one of considerable difficulty, as the two rocks come into contact with one another at the foot of Wastwater.

The metamorphism produced by the Ennerdale granophyre is pretty considerable, though no detailed study has been made of its effects. Good examples of the metamorphism undergone by the Skiddaw Slates may be obtained in the vicinity of Scale Force.

The Eskdale Granite.—This rock extends from the foot of Wastwater to the northern flanks of Black Combe. It consists of red felspar, quartz, and dark mica. The felspars are both orthoclase and plagioclase, and the triclinic potash-felspar microcline also occurs.

The rock is clearly a laccolitic intrusion, as shown by the manner in which tongues extend up the valleys, *e.g.*, at Wastwater and up Miterdale and Eskdale, and by the existence of a small isolated patch of volcanic rock on its upper surface, near Boot, on a hill called Great Barrow. It is probable that the junction with the volcanic rocks is in all cases that of the upper surface of the laccolite, and we may suspect from its position that the rock was forced along the same plane as that which determined the lines of intrusion of the Ennerdale and St. John's rocks.

The metamorphism by this granite, so far as it has been studied, appears to be of very much the same type as that which has been described in connection with the granite of Shap.

Garnet-bearing Rocks below the Banded Ashes of Scawfell.—I have left until now the consideration of a very remarkable group of rocks which is very widely spread among the Green Slates and Porphyries of the district, but which nowhere attains so great importance as just below the great series of banded ashes which form the upper portions of Scawfell and its satellites. I have already had to notice the occurrence of well-formed garnet-crystals in the undoubted lavas of the Falcon Crag series, and they are also present in undoubted intrusive rocks, for instance, in the well-known Armboth dyke. They also occur in ashes and breccias, though how far the latter are explosive breccias is as yet doubtful, but their presence in true ash (*e.g.*, that between Ward's lavas Nos. 1 and 2 on Falcon Crag) is indubitable. Two interesting questions arise concerning the rocks we are at present considering, viz., whether the rocks are contemporaneous lavas or intrusive igneous rocks, and whether the garnets are original or secondary. It is known that original garnets occur in igneous rocks, as, for instance, at Nathrop, in the Colorado district, with which some of our rocks present certain resemblances. The evidence on this point is at present indecisive, and I can only record my opinion, formed after considerable study of the rocks in the field, that the garnets of the Lake District igneous rocks are also original.

The normal rock is greyish or greenish, with a compact base in which are situated fairly large porphyritic felspars and often augites. The garnets vary in quantity, being sometimes sparsely distributed, at other times very thickly, as on Gunson Knotts, Crinkle Crags, and Illgill Head, Wastwater. In some places a nodular rock is found, as at the summit of Kidsty Pike, near Haweswater. It may be noticed that similar nodules occur in places in the Armboth dyke.

When the rock is cleaved very marked changes may occur in it. The garnets become replaced by chlorite, or mica, as before stated, and a number of secondary minerals may be developed in the rock itself. Sometimes the cleavage planes are bent in abrupt zigzags. These changes may be seen in dykes on the hillside east of Watendlath Tarn.

The rock is often brecciated, though, as observed before, the origin of these breccias is doubtful.

A peculiar and very interesting type of the rock is somewhat widely distributed. We have been accustomed to speak of it as the "streaky" type—a sufficiently expressive term, though the streaks may not always originate in the same way. Sometimes lenticular linear streaks of a darker colour are found in the rock. At others, long ribbon-like patches are seen, and

occasionally these are found to flow round eyes of rock, which bear a resemblance to fragments of lava. In some cases the streaks are probably patches of rocks of different appearance to the main mass, which have been flattened out as the result of pressure applied after the consolidation of the rock. At other times the structure is so remarkably like the flow structure of an igneous rock, that one can hardly avoid the conclusion that it was impressed on the rock prior to its consolidation. Excellent examples of this type of rock occur on the path from Stockley Bridge to Sty Head Tarn, while many varieties of the "streaky" rock are found in the Langstrath valley. The rocks will be studied in each of these localities.

A description of these rocks may be concluded with a few remarks bearing upon their origin.

A minor sill, of quite normal appearance, is visible on the path from Stonethwaite to Dock Tarn. At the upper surface the garnet rock is seen to send veins into the overlying banded ashes, and fragments of the latter are included in the garnet rock. Furthermore, the ash appears to have been altered at the contact, for a band of spotted rock is found at a distance of about an inch from the actual contact. Immediately above these ashes, and on the south side of the footpath, is another garnet-bearing rock, which is probably a lava.

At Blea Crag, in the Langstrath valley, is a complex of igneous rocks, the relationship of which has not yet been fully worked out. Some, if not all, of these rocks contain garnets, and the whole mass is clearly intrusive. This is one of the many laccolitic masses, which have been mapped as intrusive, which contain garnets.

Again, garnet-bearing dykes become very abundant in the neighbourhood of the main mass of garnet rock. These dykes, as well as the sills and laccolitic masses, have frequently undergone great change as the result of pressure, which suggests that they were all formed at a time prior to that of most of the other intrusive igneous rocks of the district.

The flinty type of ash is mainly found where the Scawfell ashes lie above the garnet-rock. The latter is specially developed in the High Street range and in the Scawfell district, and there the flinty ashes predominate. Again, the garnet-rock is found somewhat low down on the flanks of Helvellyn, and accordingly the flinty type of ash is seen near the base, at no great height above the garnet-rock, while the ashes near the summit do not show this type of alteration. These facts suggest the production of flinty texture, as the result of metamorphism by the garnet rock.

I am inclined to think, therefore, that the evidence, on the whole, points to the intrusive character of the great bulk of these garnet rocks, though it is very desirable that more evidence should be gathered.

The Shap Granite is the only other important igneous rock of considerable extent which is found in the district. As it lies away from the area to be visited by the Association, I need not give a description of it. The rock itself is sufficiently well known.

In addition to the large masses there are some smaller ones, which merit notice. Professor Bonney has described a hornblende-picrite from Little Knott. The well-known rock of Castle Head, Keswick, has received attention, as Mr. Ward suggested that it might mark the vent of one of the Lake District volcanoes, a suggestion which is confronted with some difficulties. The rock is very rotten, and of little interest. It is a dolerite or diabase. Lastly, there is the sill connected with the plumbago mine, which Mr. Ward describes as "highly altered diorite lying between two other masses of intrusive blue trap (diabase) of a compact character."

Countless dykes and minor sills and laccolites are scattered through the district, but apart from knowledge of the main masses with which they are connected, their description would be of very little interest.

In concluding this account of the rocks of the district, I would point out that in this area, where there is evidence of profound earth-movements affecting rocks, many of which from their composition are peculiarly adapted to undergo chemical changes, it is only around the masses of igneous rock that we meet with rocks comparable in composition and characters with those which are characteristic of an area of "crystalline schists."

F.—GLACIAL AND POST-GLACIAL DEPOSITS, ETC.

The accumulations of till, with their associated stratified sands and gravels, which occupy the low ground surrounding the district, extend up some of the valleys, and occasionally occupy high ground, as on Matterdale Common. Towards the head of the district they are usually absent, and their place is taken by local glacial accumulations, which rarely occupy very extensive tracts of country, thus allowing the solid rocks to appear at the surface with great frequency. In the immediate vicinity of Keswick, till is found associated with stratified gravels, and the drift mounds which occur around the town, and project from the alluvial flat between Derwentwater and Bassenthwaite, are formed of this lowland drift.

The glacial phenomena in the interior of the district have been very fully described by Mr. Clifton Ward, and it is only necessary to allude to some of the features which the members of the Association will have an opportunity of observing during the forthcoming excursion.

Striated rocks and roches moutonnées are abundant. Good

examples may be seen in Borrodale, one of the most striking being that formed of Skiddaw Slate, on which Grange Bridge is built. Immediately opposite is a vertical cliff of volcanic rocks, which is smoothed and striated. At Sprinkling Tarn it will be noticed that the escarpments of flinty ash have merely had their edges modified by ice-action.

Moraines are abundant, especially in the upland valleys. Lateral moraines are not very readily detected, as the depression which once existed between the hillside and the moraine has usually been filled up subsequently with screes and rain-wash. A well-marked lateral moraine will be noticed at the foot of Greenup Gill.

Several interesting moraines occur near Rosthwaite. The lowest is seen standing upon striated rock at the foot of the great alluvial flat. The next starts from the end of the ridge separating the Stonethwaite and Seathwaite valleys, and runs round to Rosthwaite, being plastered against the south side of the rocks under which part of the hamlet nestles. A well-marked moraine occurs at the lower end of the Seathwaite valley just above Seatoller.

In the Stonethwaite valley they are abundant. One occurs at the bottom of the valley, and a number of others may be traced up the Langstrath valley, each having given rise to a tarn, now replaced by alluvium, and having also diverted the drainage. The most striking case has been figured in the *Geographical Journal*, but it will be noticed that at the foot of each alluvial flat is a rocky gorge, with moraine-material on one side of it.

Many moraine mounds will be seen near Stockley Bridge, and also at the head of the valley which descends from Honister Pass to Seatoller.

Mr. Ward has referred to the comparative rarity of perched blocks. They are tolerably abundant on the plateau by Sprinkling Tarn. The visitors will have ample opportunity of noticing other boulders, especially those of volcanic material resting on the Skiddaw Slate, showing the general northerly movement of the ice about Keswick. The well-known Bowder Stone is not a boulder, but a mass of rock which has fallen from the cliffs above, probably down a snow-slope. Such falls must be frequent, and the writer found evidence of a very considerable one which must have occurred at the end of the present winter from the combe on Gale Fell, at the head of Mosedale, near Crummock.

The post-glacial accumulations consist of soil, screes, rain-wash, peat on mountain slopes and elsewhere, river-alluvia, and lacustrine deposits. Of these it is only necessary to notice the last mentioned accumulations.

The present lakes are gradually being filled up with mechanical detritus, shell-marl, and diatomaceous deposits, while peat usually forms the surface-accumulation after the lake has been

converted into marsh. The deposition of material must have been fairly continuous since the lakes were formed, and accordingly most of the smaller ones have already been filled up and converted into alluvial flats. Occasional sections are exposed, and exhibit the nature of the deposits. Shell-marl occurs at the base of a peat-bog around a small tarn termed Haweswater, near Silverdale, on the southern edge of the district. Mr. Strahan has recorded diatomaceous earth among the deposits of the former Kentmere Tarn, which has been artificially drained, and Mr. J. Bolton detected a diatomaceous earth surmounted by nearly 100 feet of other deposits at Lindale Cotes, near Ulverston. Clay with vegetable remains is fairly abundant. This clay is sometimes contorted and contains small boulders; when in this state it was probably deposited before glacial conditions had altogether disappeared from the district.

G.—OBSERVATIONS ON THE PHYSIOGRAPHY OF THE DISTRICT.

The radial arrangement of the main drainage lines from a point about Scawfell has been frequently noticed and discussed. Subsequently to the initiation of these main lines of river-drainage, secondary changes have occurred, and complicated, without in any way masking, the original drainage. Some of the secondary changes were due to ordinary events in the history of a land area, while others have been caused by glacial interference. The members of the Association who visit Lakeland will have opportunities of studying minor examples of each of these.

The rivers in the lower parts of the valleys have in most cases established their base-lines of erosion, being no doubt aided therein, in the case of those valleys occupied by lakes, by the raising of the water level at the lake-heads. In upland regions the base-lines have not yet been fully established in every case, and, accordingly, while the mountain-slopes present the curves of stream-erosion, they are often complicated by the existence of minor precipices and steep slopes. This is naturally seen more frequently among the very variable rocks of the volcanic series than among the softer and more uniform rocks of the Skiddaw Slates, and, accordingly, the curve in the latter is often unbroken, while in the former it is interrupted by alternating gentle and steep slopes.

The upper parts of many of the hills are frequently occupied by vegetation, and there the curve of stream erosion is replaced by a convex curve of weathering. This is specially seen on the slopes which face westward and southward, while on the north and east sides the curve of stream-erosion may be frequently traced to the summit of the mountain. There are exceptions to

this, as when the valley on the south or west is at a much lower level than that on the north or east. One very striking example is Saddleback. On the south side of this hill the regularity of river-valleys which have been initiated in rocks of uniform composition, when other conditions are also uniform, may be well studied from the railway between Troutbeck and Threlkeld stations. A series of buttresses, at fairly regular distances apart, separate deep combes hollowed out of the mountain side.

Upland valleys often end suddenly against the mountain side, and the stream from them flows in cascades down the side of the main valley, without cutting out any appreciable depression. Many of these are seen on the east side of Helvellyn, and one or two in the Langstrath valley. The Watendlath valley terminating in Lowdore waterfall is a very striking case. The explanation of the occurrence need not necessarily be the same in each case.

Many of the waterfalls in the district are due to glacial interference, for instance the small one at the foot of one of the alluvial flats, to which reference has already been made. Others as obviously are not connected with such interference. One of the most noteworthy of these is Scale Force, near Crummock, which owes its existence to the juxtaposition of soft Skiddaw Slate and hard granophyre. It is probably of no great antiquity, as the fall has not receded very far, and it is probably post-glacial.

In the higher parts of the district many remarkable gorges, similar to the roflas of Switzerland, are seen. They are usually excavated along dykes, faults, or mineral veins. Of these, Peers Gill, which may be seen from the top of Sty Head Pass, is one of the most remarkable. Similar roflas possibly existed in the lower parts of the district, but have been filled with glacial accumulations.

The influence of the dominant planes of weakness in the rocks upon the superficial features may be admirably seen about Sty Head and Sprinkling Tarns. Peers Gill has a Z-shaped course, determined by two sets of planes at right angles to one another. The east side of Sprinkling Tarn and the corresponding side of the fairy-like High House Tarn are determined by one plane, and the courses of the gills in the neighbourhood were clearly determined by similar planes.

I have touched on a few points only in connection with the scenery of the district and its dependence upon the geology. Many others will doubtless be detected and discussed by the members of the Association who visit the district, and we may reserve their consideration until they can be regarded on the spot.

The fossils of the Keswick district are few and far between; the problems connected with the rocks in many cases obscure; but I know of no fairer field for the study of physiography, and I have tried to plan the excursions in such a way that study of the

ZONAL FEATURES OF THE CHALK PITS IN THE ROCHESTER, GRAVESEND, AND CROYDON AREAS.

By G. E. DIBLEY, F.G.S.

(Read April 6th, 1900)

THE object of this paper is to describe the chalk pits in the Rochester, Gravesend, and Croydon areas, and to provide a list of the organic remains found therein by the author, in order to determine the horizons of the Chalk exposed. The localities of the pits are indicated by the numbers on the accompanying maps. Each pit is distinguished by a corresponding number in the text.

I have not found any specimens of *Uintacrinus* or of *Marsupites* in the course of my six years of diligent collecting, and this seems to show that there is no chalk in the area under discussion newer than that of the zone of *Micraster cor-anguinum*.

The solitary specimen of *Actinocamax merceyi* from "The Quarry," Strood, is of interest, as Dr. Rowe's lowest record for the same species is about 30 ft. below the "Bedwell Line" at Margate. The occurrence also of *Actinocamax verus* and of *A. merceyi* at Cliffe is highly suggestive of the *Marsupites*-zone. Dr. Rowe's specimen of *A. merceyi* came from the *Uintacrinus*-band of the *Marsupites*-zone, and it is therefore possible that some vestige of that band may yet be found in the Rochester-Gravesend area.

The fact that collecting in pit sections has almost always to be done from fresh surfaces makes it exceedingly difficult to find such small organisms as isolated plates of *Uintacrinus*.

ROCHESTER DISTRICT.

STROOD.—The large pits, known as "The Quarry" (1), north-east of Strood Station, are in the *Micraster cor-anguinum*-zone. The chalk is soft and flints abundant; it is worked to a depth of from 50 to 80 feet. The general dip is to the north. The predominant fossils are *Micraster cor-anguinum*, *Echinoconus conicus*, and *Echinocorys vulgaris*. Only one specimen of *Actinocamax merceyi* has been recorded from these pits, and this has been presented to the British Museum by Mr. W. H. Ball.

We have here an horizon lower than that of the Gravesend area, as proved by the dip, and by the fact that forms characteristic of that district are rare.

Messrs. Martin and Earle's pits (2) are situate to the west of the old South-Eastern line.

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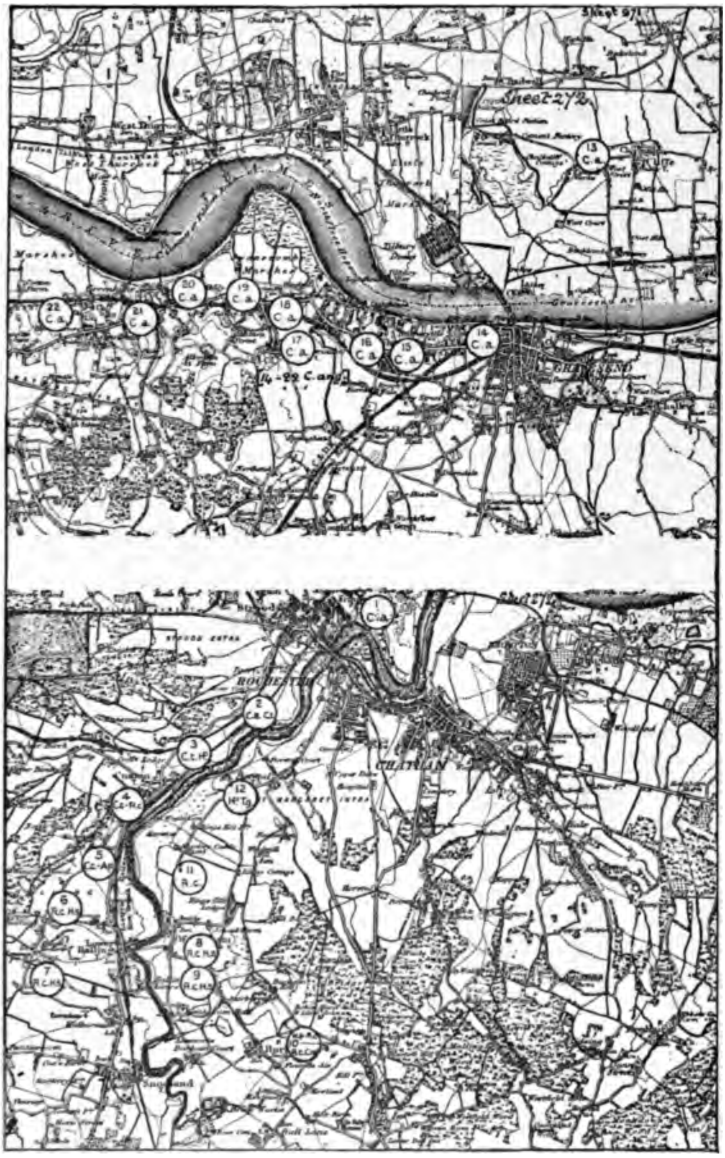

MAPS OF THE GRAVESEND AND ROCHESTER AREAS. Reduced from the Ordnance Survey Maps, sheets 271, 272. Scale, 1 inch = 2 miles. (Portion of Sheet 272, showing the position of pit 13, is inserted in the Gravesend map.)

The chalk is characterised by many layers of flint, both nodular and tabular; the northerly dip is well seen, and lower beds are exposed than those met with at "The Quarry." A hard band occurs at about 20 ft. from the top, which, so far as examined, contains but few fossils. About 80 to 100 ft. of chalk is exposed in this pit, and the whole of it is, I believe, in the *Micraster cor-anguinum* and *Micraster cor-testudinarium*-zones. *Micraster cor-anguinum* is the typical fossil; *Echinoconus conicus* has not yet been recorded. The downward succession, as we collect southwards, is well shown by the fauna.

Messrs. Booth and Co.'s pit (3), is about a quarter of a mile south of the last described pit, and on the western side of the railway. The cutting leading to the pit shows about 70 ft. of chalk with the hard band just referred to at the top, and one or two well-marked bands of flints, then a space of about 30 ft. with few flints, then from this flintless space downwards three other well-marked bands occur. Nodular chalk extends to the base.

The Micrasters found here belong to the *M. cor-testudinarium* and *M. præcursor* groups, the essential details of the ornament of the test showing that they belong to a lower horizon than those from the pits previously described. *Holaster planus* has not been recorded, but the Micrasters show that we are in the immediate neighbourhood of, if not actually in, the *Holaster planus*-zone.

The Cuxton Pit belonging to Messrs. Weekes and Trechmann (4) opposite Whorne's Place, was visited by the Association last year.* Many of the specimens in the British Museum, labelled "Whorne's Place, Rochester," are from this pit.

From 200 to 300 ft. of chalk are exposed. Well-marked bands of flint occur near the top, with scattered flints, and one or two bands below, in a hard, nodular and iron-stained chalk. The lower portion of the pit is in a compact flintless chalk with very few fossils. The upper part has yielded a rich fauna.

Micrasters of the *M. cor-testudinarium* and *M. præcursor* groups are common, *M. leskei* is rare, and I have only one specimen of *M. cor-bovis*, and one of *M. cor-anguinum*. *Holaster planus* and *Terebratulina gracilis* are abundant. *Pentacrinus* columnars are frequently met with in the *Holaster planus*-zone. *Echinoconus subrotundus* occurs; *Rhynchonella cuvieri* is fairly abundant. *Cyphosoma radiatum* is a reliable zone-fossil at this horizon.

From a study of the Echinoderms it is evident that we have in this pit probably a capping of *M. cor-anguinum*-zone, the *M. cor-testudinarium*-zone, that of *Holaster planus*, and of *Terebratulina gracilis*, and possibly the upper part of *Rhynchonella cuvieri*-zone.

Messrs. Formby and Co.'s pit (5) about half a mile south of the last, shows a section similar to that seen in the pit last described.

* *Proceedings*, vol. xvi, p 249.

By following the tramway from this pit, we enter other large pits on the right, worked in the zone of *Rhynchonella cuvieri*. The bases of the pits evidently are in the *Actinocamax plenus*-band as can be seen by the dip of this bed in the pits (No. 6).

Messrs. Hilton, Anderson and Co.'s pits (6).—The upper pits are in the *Rhynchonella cuvieri*-zone. At about 30 ft. from the base the *Actinocamax plenus*-band is seen. *Discoidea cylindrica* has been obtained recently from this part of the pit. A notable feature here is the denudation of the Chalk, leaving a valley between the pits and the Down on the west. The frequent occurrence of gravel pipes, but rarely to be seen in the pits previously visited, is also noteworthy.

Messrs. Lee and Co.'s pits at Holborough (7).—The zones of *Rhynchonella cuvieri*, *Actinocamax plenus*, and *Holaster subglobosus* are here well seen. This is the last of the large excavations on the western side of the Medway. It is probable that specimens in various museums labelled "Snodland" came from these pits. *Hippurites* are sometimes found in the *Rhynchonella cuvieri*-zone of this area. *Discoidea cylindrica* is obtained here, though not previously recorded from the *Holaster subglobosus*-zone on the eastern side of the Medway.

BURHAM DISTRICT.

"The Free School Pit" (8) has yielded a fine specimen of *Hippurites*. Here the zones range from *Rhynchonella cuvieri* to *Holaster subglobosus*.

On the right are large excavations belonging to Messrs. Peters and Co. (9), extending to Upper Burham. The *Actinocamax plenus*-zone is distinctly seen, capped by the *Rhynchonella cuvieri*-zone, and forms a marked feature from 10 to 20 ft. below the top of the pit; the lower portion is in the *Holaster subglobosus*-zone.

The writer is strongly of opinion that the Chalk is here faulted and folded, and that the Medway has cut its way through a line of fault, as the corresponding zones on the west side of the river are at a much higher elevation. For instance, though the *Actinocamax plenus*-zone is not reached at Messrs. Weekes and Trechmann's pits (4), here at Messrs. Peters and Co.'s pits it is about 80 ft. above the river; while at Blue-Bell Hill Pits (10) it is fully 300 ft. above the river.

The Blue-Bell Hill Pits (10), locally known as "The New Found Out," form a prominent feature in the landscape, being cut into the North Downs, which here reach nearly 700 ft. O.D. These pits probably afford one of the finest inland sections of Chalk in England.

Two pits are seen, the upper and the lower, *Holaster subglobosus*

and *Holaster trecensis* are obtained in the lower pit together with *Ammonites rhotomagensis*. The Chalk Marl is of a creamy colour, and easily distinguished from the overlying white beds. The upper portion of the lower pit contains the *Actinocamax plenus*-zone, and above it occurs a hard band, locally known as "soap," containing casts of *Inoceramus mytiloides* (=*labiatus*), and forming the division between the lower and the upper pit. In the upper pit nearly 300 ft. of chalk are exposed, consisting of the *Rhynchonella cuvieri*-zone, the *Terebratulina gracilis*-zone, and the *Holaster planus*-beds. The same features in the chalk are met with here, 600 ft. above the river, as at Whorne's Place, Cuxton, and *Echinoconus subrotundus* and *Pentacrinus* are plentiful. Owing to the steep angle of the workings in this and in the Cuxton district, it is difficult to determine the exact limitation of the zones by personal collection of the fossils. Micrasters are very rare; I have found *Micraster cor-bovis* and *Micraster leskei*. Vertebrates, chiefly fishes, occasionally occur. Otherwise the pits have yielded a rich fauna, as exemplified by the list at end of this paper and the specimens in the British Museum.

Messrs. Tingey and Co.'s large pit (11) is situated half-a-mile north of Wouldham. The chalk is worked to a depth of about 80 ft., the base of the pit being about 30 ft. above the river. *Echinoconus subrotundus* is fairly abundant. The zones are those of *Terebratulina gracilis* and of *Rhynchonella cuvieri*.

Borstal Manor Pit (12), owned by Messrs Booth and Co., is situated about a mile north of that last described. The section here worked is about 70 ft. The chalk and its fossils correspond with those of the upper part of the Whorne's Place pit on the western side of the Medway. *Holaster planus*, *Terebratulina gracilis*, *Rhynchonella cuvieri*, and *Pentacrinus* are found in this pit; while on the opposite side of the river, at Messrs. Martin and Earle's pit (2) and at a slightly lower elevation the first three low-zonal fossils are not met with. The hard blocky chalk with few flints is seen in this pit and there is a well marked band of large flints about 20 ft. from the top. The zones are those of *Holaster planus* and *Terebratulina gracilis*. Three prominent marly bands are seen in the disused portion of the pit, one just under the flints, one near the centre, and a third near the base.

Cliffe (13) is about five miles north of Strood.—The chalk here is worked for about 70 ft., and is of the same lithological and zoological facies as that in the Gravesend area, being very soft and friable. It contains decidedly higher zonal forms than those in the neighbourhood of Strood. The carinated form of *Micraster cor-anguinum*, also *Echinoconus conicus*, *Cyphosoma königi*, *Actinocamax verus*, and *A. merceyi* are common; *A. westphalicus* has been obtained. From the association of these fossils we should expect to find traces of the *Marsupites*-zone. Information on this point is desirable.

GRAVESEND DISTRICT.

Gravesend, Northfleet, Swanscombe, and Farningham Road (numbered 14—25).—All the pits in this district are at about the same horizon, viz., that of *Micraster cor-anguinum*. The chalk is very soft, and the flints form prominent bands, both nodular and tabular.

The fauna includes the carinated form of *Micraster cor-anguinum*, which is abundant, also *Echinocorys vulgaris* with its varieties, and *Echinoconus conicus*. The *Echinoconus* is typical, and there is also a well-marked variety somewhat resembling *E. subrotundus* of the *Rhynchonella cuvieri*-zone.

Janira quinquecostata is but rarely found. Dr. Arthur Rowe obtained a specimen of *Holaster placenta* from this area (Tolhurst's pit, 15).

A fine specimen of *Ammonites* of the *leptophyllus* group has been recently obtained by Mr. W. Tolhurst, the proprietoi of one of the pits. It is in the form of a flint cast 18 inches in diameter, and is the only one known to the writer during six years' work in this locality, with the exception of an *Aptychus* and an *Ostrea* bearing the impression of ammonitoid sutures. Dr. Sharpe's type specimen of *Ammonites leptophyllus* is said by him to have come from this neighbourhood.

By referring to the list appended it will be seen that the Cidaridæ and Asteridæ are abundant, as are corals of the *Parasmilia* type and also *Bourgueticrinus*. In the Rochester area these forms are exceedingly rare in the Chalk, but spines, plates, and occasionally whole tests of *Cyphosoma* are found, upon, or embedded in flints. Vertebrates are rare, teeth of *Lamna* and *Corax* excepted; *Ptychodus* is very seldom met with.

Mr. Frederick Chapman has given a list of the Foraminifera from this horizon (*Proc. Geol. Assoc.*, vol. xiii, 1894, p. 369).

From a small working at Cox's Mount, Charlton (25), the author has obtained fossils indicative of the *M. cor-anguinum*-zone fauna; and from Westcombe Park *Echinoconus conicus*, *Cyphosoma königi*, and the carinated form of *Micraster cor-anguinum*, have also been obtained; fossils which mark the upper part of this zone.

WESTERHAM, KESTON, AND OTFORD.

Near the top of the hill, north of Westerham (26), the *Rhynchonella cuvieri*-zone occurs.

The exposure about a mile south of Keston (27) is interesting from the fact that the fauna and the lithological characters are nearly identical with those of the chalk of the Gravesend area. The beds themselves are possibly of a slightly lower horizon. No authenticated specimen of *Belemnites* has been seen by the writer from this pit, but it is highly probable that some may yet

and *Holaster trecensis* are obtained in the lower pit together with *Ammonites rhotomagensis*. The Chalk Marl is of a creamy colour, and easily distinguished from the overlying white beds. The upper portion of the lower pit contains the *Actinocamax plenus*-zone, and above it occurs a hard band, locally known as "soap," containing casts of *Inoceramus mytiloides* (=*labiatus*), and forming the division between the lower and the upper pit. In the upper pit nearly 300 ft. of chalk are exposed, consisting of the *Rhynchonella cuvieri*-zone, the *Terebratulina gracilis*-zone, and the *Holaster planus*-beds. The same features in the chalk are met with here, 600 ft. above the river, as at Whorne's Place, Cuxton, and *Echinoconus subrotundus* and *Pentacrinus* are plentiful. Owing to the steep angle of the workings in this and in the Cuxton district, it is difficult to determine the exact limitation of the zones by personal collection of the fossils. Micrasters are very rare; I have found *Micraster cor-bovis* and *Micraster leskei*. Vertebrates, chiefly fishes, occasionally occur. Otherwise the pits have yielded a rich fauna, as exemplified by the list at end of this paper and the specimens in the British Museum.

Messrs. Tingey and Co.'s large pit (11) is situated half-a-mile north of Wouldham. The chalk is worked to a depth of about 80 ft., the base of the pit being about 30 ft. above the river. *Echinoconus subrotundus* is fairly abundant. The zones are those of *Terebratulina gracilis* and of *Rhynchonella cuvieri*.

Borstal Manor Pit (12), owned by Messrs Booth and Co., is situated about a mile north of that last described. The section here worked is about 70 ft. The chalk and its fossils correspond with those of the upper part of the Whorne's Place pit on the western side of the Medway. *Holaster planus*, *Terebratulina gracilis*, *Rhynchonella cuvieri*, and *Pentacrinus* are found in this pit; while on the opposite side of the river, at Messrs. Martin and Earle's pit (2) and at a slightly lower elevation the first three low-zonal fossils are not met with. The hard blocky chalk with few flints is seen in this pit and there is a well marked band of large flints about 20 ft. from the top. The zones are those of *Holaster planus* and *Terebratulina gracilis*. Three prominent marly bands are seen in the disused portion of the pit, one just under the flints, one near the centre, and a third near the base.

Cliffe (13) is about five miles north of Strood.—The chalk here is worked for about 70 ft., and is of the same lithological and zoological facies as that in the Gravesend area, being very soft and friable. It contains decidedly higher zonal forms than those in the neighbourhood of Strood. The carinated form of *Micraster cor-anguinum*, also *Echinoconus conicus*, *Cyphosoma königi*, *Actinocamax verus*, and *A. merceyi* are common; *A. westphalicus* has been obtained. From the association of these fossils we should expect to find traces of the *Marsupites*-zone. Information on this point is desirable.

GRAVESEND DISTRICT.

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present visible, the excavation of a few feet of the floor of the pit would no doubt expose it.]

The Oxted Lime Pit (34) is situate in the *R. cuvieri*-, *Actinocamax plenus*- and *Holaster subglobosus*-zones. *Discoidea cylindrica* occurs.

In conclusion, I beg to tender my sincere thanks, for assistance in the preparation of this paper, to Dr. A. Smith Woodward, Mr. G. C. Crick, Mr. A. J. Jukes-Browne, Mr. Henry Woods, Mr. F. Chapman, Dr. G. J. Hinde, Mr. E. T. Newton, Dr. F. L. Kitchin, and particularly to Dr. Arthur Rowe, and Mr. C. D. Sherborn for their invaluable aid in naming and zoning the fossils in the following list.

LIST OF FOSSILS FROM THE CHALK OF THE ROCHESTER, GRAVESEND, AND CROYDON AREAS.

In the table of fossils the pits are referred to by the numbers used in the descriptive text and on the maps; the *letters* following the number referring to the *zones*, as follows:

a = Zone of *Micraster cor-anguinum*.
b = „ „ *cor-testudinarium*.
c = „ *Holaster planus*.
d = „ *Terebratulina gracilis*.
e = „ *Rhynchonella cuvieri*.
f = „ *Actinocamax plenus*.
g = „ *Holaster subglobosus*.
h = „ Chalk Marl.

In those cases where it is difficult or impossible to exactly fix the zone from which the fossil came, the number of the pit alone is given.

Pits 14-22, so often quoted, are those in the Gravesend area. They are all in the *Micraster cor-anguinum*-zone, and may be separately enumerated for convenient reference as follows:

14. Messrs. Fletcher & Co.	19, 20. Messrs. White & Co.
15. Messrs. Tolhurst & Co.	20. Swanscombe.
16. The London Portland Co.	21. Greenhithe.
17. Messrs. Beavan & Co.	22. Draper's Pit.
18. Messrs. Kirby & Co.	

PLANT REMAINS.

Coniferous wood	1 *a*; 7 *g*; 10 *g*; 14 *a*; 30 *a*; 32 *d*.

INVERTEBRATA.

Heterostinia obliqua, Benett . .	16 *a*.
Siphonia königi, Mant. . . .	4.
Plinthosella, spp.	1 *a*; 2 *a*; 3 *b*; 4 *c*, *d*; 13 *a*; 14-22 *a*; 24 *a*; 27 *a*; 30 *a*; 31 *b*.
Coscinopora infundibuliformis, Goldf. .	14 *a*; 26.
Ventriculites decurrens, T. Smith .	4 *c*, *d*; 10 *c*, *d*; 28 *a*; 33 *c*.
„ *mammillaris*, T. Smith .	4 *c*, *d*; 10 *c*, *d*; 28 *a*.
„ *impressus*, T. Smith .	4 *c*, *d*; 28.

Ventriculites radiatus, Mant.	1 *a*; 4; 10; 14-22 *a*; 30 *a*.
„ *alcyonoides*, Mant.	14-22*a*; 24*a*.
Pharetrospongia strahani, Sollas.	1 *a*; 14 *a*; 24 *a*; 27 *a*.
Porosphæra globularis, Phil.	1 *a*; 2 *a*,*b*; 3 *b*; 4 *b*,*c*,*d*; 10 *c*,*d*; 13 *a*; 14-22; 24 *a*; 27 *a*; 30 *a*.
„ *pileolus*, Lam.	14-22 *a*; 24 *a*; 30 *a*; 31 *b*.
„ (branching form)	14 *a*.
Cephalites longitudinalis, T. Smith	4; 10.
„ *catenifer*, T. Smith	4.
„ *perforatus*, T. Smith	4.
Camerospongia capitata, T. Smith	4.
Plocoscyphia convoluta, T. Smith	1 *a*; 2 *a*, *b*; 4 *b*, *c*; 10 *b*,*c*; 14-22 *a*; 24 *a*; 26; 30 *a*; 31 *b*; 33 *c*.
Parasmilia centralis, Mant.	1 *g*; 4; 14-22 *a*; 24 *a*; 27; 30 *a*.
„ *granulata*, Dunc.	14-22 *a*.
„ *cylindrica*, E. & H.	14-22 *a*.
Axogaster cretacea, Lonsd.	7 *g*; 10 *c*.
Synhelia sharpeana, M. Edwds.	30 *a*.
Bourgueticrinus ellipticus, Nils., varr.	1 *a*; 2 *a*, *b*; 3 *b*, *c*; 10 *c*; 13 *a*; 14-22 *a*, 24 *a*; 30 *a*; 31 *b*; 33 *c*.
Pentacrinus (columnars)	4 *c*; 10 *c*; 12 *c*; 32 *c*; 33 *c*.
Ophiura serrata, Roemer	15 *a*.
Oreaster obtusus, Forbes	15 *a*.
Mitraster hunteri, Forbes	14-15 *a*; 27 *a*.
„ *rugatus ?* Forbes	14 *a*.
Pentagonaster megaloplax, Sladen	14-15 *a*; 24 *a*; 27 *a*.
Metopaster parkinsoni, Forbes	15 *a*.
„ *mantelli*, Forbes	15 *a*.
Calliderma latum, Forbes	14 *a*.
Nymphaster coombii ? Forbes	15 *a*.
Cidaris sceptrifera, Mant.	1 *a*; 2 *a*; 4 *b*; 14; 22 *a*; 24 *a*; 27 *a*; 30 *a*.
„ *clavigera*, König	4 *c*; 14-22 *a*; 24 *a*; 27 *a*.
„ *perornata*, Forbes	14 *a*; 17 *a*.
„ *hirudo*, Sorig.	4 *c*; 33 *c*.
„ *serrifera*, Forbes	14-22 *a*.
Cyphosoma königi, Mant.	1 *a*; 13 *a*; 14-22 *a*; 24 *a*; 27 *a*; 30 *a*.
„ *corollare*, Klein	13 *a*; 14-22 *a*; 24 *a*; 30 *a*.
„ *radiatum*, Sorig.	4 *c*; 10 *c*; 12 *c*; 32 *c*; 33 *c*.
Echinocorys vulgaris, Breyn.	All pits containing zones *a* to *c*.
Echinoconus conicus, Breyn.	1 *a*; 13 *a*; 14-22 *a*; 24 *a*; 27 *a*.
„ „ var.	13 *a*; 14-22 *a*; 27 *a*.
„ *subrotundus*, Mant.	4 *d*; 5 *d*; 10 *d*; 11 *a*; 26; 28; 32 *a*; 33 *d*.
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Discoidea dixoni, Forbes	26.
„ *cylindrica*, Lam.	6 *g*; 7 *g*; 34 *g*.
Pseudodiadema ornatum, Goldf.	10 *g*.
Micraster cor-anguinum, Leske	1; 2; 13; 14-22; 24; 27; 30; 31.
„ „ var. *latior*, Rowe	14-22 *a*; 27 *a*.
„ *præcursor* (group)	3 *b*,*c*; 4 *b*, *c*, *d*; 5; 31 *b*; 32 *b*,*c*; 33 *c*.
„ *cor-testudinarium*, Goldf.	3; 4; 31.
„ *leskei*, Desm.	3; 4.
„ *cor-bovis*, Forbes	4 *c*; 10 *c*.
Epiaster gibbus, Lam.	1 *a*; 13 *a*; 14-22 *a*; 24 *a*; 27 *a*; 30 *a*.
Holaster planus, Mant.	4; 5; 10; 12; 32; 33.
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Epiaster gibbus, Lam.	1 *a*; 13 *a*; 14-22 *a*; 24 *a*; 27 *a*; 30 *a*.
Holaster planus, Mant.	4; 5; 10; 12; 32; 33.
„ *placenta*, Ag.	15 *a*; 30 *a*; 31 *b*.

Holaster trecensis, Leym.	7 *g*; 9 *g*; 10 *g*.
„ *subglobosus*, Leske	7; 9; 10; 34.
Cardiaster, large n. sp.	1 *a*.
Serpula ampullacea, Sby.	1 *a*; 7 *g*; 9 *g*; 10 *g*; 14-22 *a*.
„ *fluctuata*, Sby.	1 *a*; 14-22 *a*.
„ *ilium*, Sby.	1 *a*; 4.
„ *macropus*, Sby.	1 *a*.
„ *plana*, S. Woodw.	1 *a*; 14-22 *a*.
„ *plexus*, Sby.	1 *a*; 14 22 *a*.
Crania parisiensis, Defr.	14-22 *a*; 24 *a*; 27 *a*.
Thecidea wetherelli, Morris.	14-22 *a*; 24 *a*.
Kingena lima, Defr.	14-22 *a*; 24 *a*.
Terebratulina striata, Dav.	12 *c*; 24 *a*; 31 *b*; 32 *c*.
„ *gracilis*, Schl.	4 *b*, *c*; 10 *b*, *c*; 12 *c*, *d*; 27 *a*; 31 *b*; 32 *c*, *d*; 33 *c*.
Terebratula semiglobosa, Sby.	1 *a*; 2 *a*, *b*; 3 *a*, *b*, *c*; 4 *b*, *c*, *d*; 5 *c*, *d*; 10 *c*, *d*; 11 *d*, *c*; 12 *c*, *d*; 13 *a*; 14-22 *a*; 24 *a*; 27 *a*; 30 *a*; 31 *a*.
„ *carnea*, Sby.	29 *g*; 30 *a*; 31 *b*; 34 *g*.
Rhynchonella reedensis, Eth.	13 *a*; 14-22 *a*; 24 *a*; 27 *a*.
„ *cuvieri*, d'Orb.	4 *c*, *d*, *e*; 5 *c*, *d*, *e*; 10 *c*, *d*, *e*; 12 *c*, *d*; 32 *c*, *d*; 33 *c*, *d*.
„ *woodwardi*, Dav.	4 *c*; 12 *c*.
„ *plicatilis*, Sby.	4 *b*, *c*; 12 *c*; 13 *a*; 14-22 *a*.
„ *octoplicata*, Sby.	13 *a*; 14-22 *a*.
„ *mantelliana*, Sby.	10 *h*.
Pecten nitidus, Mant.	1 *a*; 13 *a*; 14-22 *a*; 24 *a*; 27 *a*; 30 *a*.
„ *arachnoides*, Defr.	14 *a*.
„ *concentricus*, Woodw.	30 *a*.
„ *beaveri*, Sby.	9 *g*; 10 *g*.
„ *jugosus*, Sby.	9 *g*; 10 *g*.
„ *orbicularis*, Sby.	10 *g*; 10 *h*.
„ n. sp.	30 *a*.
„ n. sp.	10 *g*.
„ n. sp.	10 *g*.
„ n. sp.	10 *g*.
„ n. sp.	19 *a*.
Janira quinquecostata, Sby.	14 *a*; 16 *a*; 31 *b*.
Spondylus spinosus, Sby.	All pits containing zones *a to c*.
„ *dutempleanus*, d'Orb.	14 *a*.
„ *latus*, Sby.	1 *a*; 13 *a*; 14-22 *a*; 27 *a*.
„ *fimbriatus*, Sby.	4; 14 *a*; 15 *a*; 24 *a*.
Lima hoperi, Mant.	1 *a*; 2 *a*, *b*; 4 *b*, *c*; 5 *b*, *c*; 10; 12; 13 *a*; 14-22 *a*; 30 *a*; 31 *b*; 32 *c*.
„ *granosa*, Sby.	14 *a*.
„ *aspera*, Mant.	10 *g*.
„ *parallela*, Sby.	10 *g*.
„ n. sp.	33.
Ostrea vesicularis, Lam.	1 *a*; 10 *c*; 13 *a*; 14-22 *a*.
„ *normaniana*, d'Orb.	4 *b*, *c*; 13 *a*; 14-22 *a*; 24 *a*.
„ *semiplana*, Sby.	14-22 *a*.
„ *curvirostris*, Nils.	1 *a*; 4.
„ *hippopodium*, Nils.	7 *g*; 10 *g*.
Exogyra, sp.	7 *g*; 10 *g*.
Anomia, sp.	16 *a*.
Plicatula sigillina, Woodw.	1 *a*; 14 *a*.

Plicatula barroisi, Peron	4 *c*; 32 *c*; 33 *c*.
„ *inflata*, Sby.	10 *h*.
„ *pectinoides*, Sby.	7 *g*; 10 *g*; 34 *g*.
Pinna decussata, Goldf.	10 *g*; 14 *a*; 24 *a*.
Inoceramus lamarcki, Park.	2; 30 *a*.
„ *striatus*, Mant.	10.
„ *cuvieri*, Sby.	2; 3 *c*; 4 *c*; 5; 10 *c*, *d*; 12; 26; 28; 33 *d*.
„ *involutus*, Sby.	1 *a*; 30 *a*.
„ *cripsi*, Mant.	10 *g*.
„ *alatus*, Goldf.	4.
„ *lingua*, Goldf.	10 *c*, *d* ?
„ *latus*, Mant.	4.
„ *labiatus*, Schl.	10 *e*.
Panopæa, sp.	10 *h*.
Arca, sp.	10 *h*.
Pholadomya decussata, Phil.	10 *h*.
Isocardia, sp.	10 *h*.
Radiolites mortoni, Mant.	4 *e*; 7 *c*; 8 *c*; 10 *d*, *e*? 11 *c*; 33 *d*.
Teredo amphisbæna, Goldf.	4; 7 *g*; 10 *g*; 15 *a*; 33 *d*.
Turbo gemmatus, Sby.	10 *c*, *d*?
Pleurotomaria perspectiva, Mant.	1 *a*; 2 *a*, *b*; 4 *b*, *c*, *d*; 9 *g*; 14-22 *a*; 32 *b*, *c*.
Solarium ornatum, Sby.	9 *g*.
Nautilus pseudoelegans ? d'Orb.	10 *h*; 32 *d*.
„ *deslongschampsianus*, d'Orb.	*h*.
Baculites, sp.	10 *h*.
Scaphites æqualis, Sby.	10 *h*.
„ *obliquus*, Sby.	10 *h*.
Ammonites leptophyllus (group)	15 *a*.
„ *pachydiscus*	4 *d*; 32 *d*; 33 *d*.
„ *rhotomagensis*, Brongn.	10 *h*.
„ *coupei*, Brongn.	10 *h*.
„ *varians*, Sby.	10 *h*.
„ *mantelli*, Sby.	10 *h*.
„ n. sp.	10 *g*.
Turrilites costatus, Lam.	10 *h*.
„ *tuberculatus*, Bosc	10 *h*.
Actinocamax verus, d'Orb.	13 *a*; 14-22 *a*.
„ *merceyi*, Mayer-Eymer	1 *a*; 13 *a*; 14-22 *a*.
„ *westphalicus*, Schlüter	13 *a*.
„ *plenus*, Blainv.	7; 8; 9; 10; 34.
„ n. sp.	14 *a*.
Aptychus	16 *a*.
Beak of Cephalopod	14 *a*.
Pollicipes unguis, Sby.	4 *c*; 10 *c*, *d*? 14 *a*; 24 *a*.
Scalpellum arcuatum, Darwin	30 *a*.
„ *maximum*, Sby.	14 *a*; 19 *a*.
Enoploclytia leachi, Mant.	4; 10 *g*; 30 *a*; 32 *d*.

VERTEBRATA.

Anomæodus cretaceus, Ag.	15 *a*; 30 *a*; 31 *b*.
Apateodus striatus, Ag.	10 *g*.
Cestracion rugosus, Ag.	1 *a*; 33 *d*.
Cimolichthys lewesiensis, Leidy	30 *a*; 33.

Cladocyclus lewesiensis, Ag.	7 *c*; 10 *c*; 30 *a*.
Corax falcatus, Ag.	4; 10 *c*, *d*? 14-22 *a*; 30 *a*; 31 *b*; 33.
Ctenothrissa (=*Beryx*) *microcephalus*, Ag.	10 *g*.
Dercetis elongatus, Ag.	4; 10 *g*.
Edaphodon mantelli, Buckl.	10 *g*.
„ sp.	9 *g*; 10 *g*; 30 *a*.
Enchodus, sp.	4; 9 *g*; 10 *g*; 30 *a*; 31 *b*; 33.
Gyrodus angustidens, Ag.	33 *e*.
Homonotus dorsalis, Dixon	10 *g*.
Ichthyodectes, sp.	30 *a*.
Lamna appendiculata, Ag.	All pits containing zones *a* to *g*.
„ *macrorhiza*, Cope	14 *a*.
„ *sulcata*, Gein.	11; 33.
Macropoma mantelli, Ag.	10 *c*.
Notidanus microdon, Ag.	10 *g*; 30 *a*.
Oxyrhina mantelli, Ag.	All pits containing zones *a* to *c*.
„ *angustidens*, Reuss	7 *g*; 14 *a*; 15 *a*; 33.
„ *macrorhiza*, Pict. and Camp.	10 *e*.
Pachyrhizodus gardneri, Mason	9 *g*; 10 *g*.
„ n. sp.	10 *g*.
Plethodus oblongus, Dixon	4 *e*; 10 *g*.
Portheus, sp.	4 *e*; 10 *g*.
Protosphyræna, sp.	4 *e*; 7 *g*; 10 *g*.
Ptychodus altior, Ag.	10 *c*, *d*? 12; 31 *b*; 33.
„ *mammillaris*, Ag.	4 *c*, *d*; 5 *c*, *d*; 10 *c*, *d* *e*; 11 *d*; 32 *d*; 33 *c*, *d*.
„ *latissimus*, Ag.	4; 10 *c*, *d*, *e*; 12 *d*; 15 *a*; 28; 30 *a*.
„ *rugosus*, Dixon	1 *a*; 30 *a*.
„ *decurrens*, Ag.	6 *g*; 7 *g*; 9 *g*; 10 *g*; 34 *g*.
„ *depressus*, Dixon, var.	6 *g*; 7 *g*; 9 *g*; 10 *g*;
„ *lævis*, A. S. W.	10 *g*.
„ *paucisulcatus*, Ag.	4; 10 *c*, *d*, *e*; 11; 12 *c*, *d*?
„ *polygyrus*, Ag.	7 *g*; 10 *d*, *e*? 11 *a*; 33 *d*; 34 *g*.
Scapanorhynchus gigas, A. S. W.	4; 10 *d*, *e*? 15 *a*.
„ *rhaphiodon*, Ag.	4; 10 *d*, *e*?
„ *subulatus*, Ag.	10; 14 *a*; 30 *a*; 33 *c*.
Shark vertebræ	10; 11; 15 *a*.
Tomognathus mordax, Dixon	7 *g*; 10 *g*.
„ sp.	
Chelonian remains	4; 10 *c*, *d*? 33 *d*.
Polyptychodon interruptus, Owen	4; 8; 10 *d*; *e*? 31 *b*.
Reptilian (paddle-bone)	10 *g*.
Rhynchocephalian ?	4 *e*.

APPENDIX.

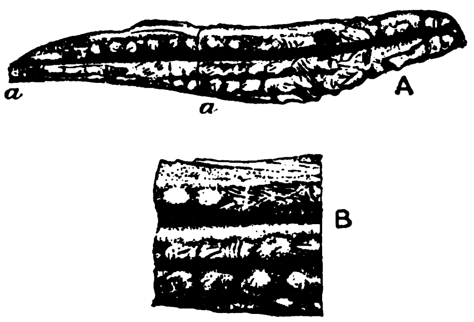
ON A REMARKABLE BONE FROM THE CHALK OF CUXTON, POSSIBLY REFERABLE TO THE RHYNCHOCEPHALIA.

By E. T. NEWTON, F.R.S., F.G.S., F.Z.S.

OUR fellow member, Mr. G. E. Dibley, an indefatigable collector of Chalk fossils, some time ago placed in my hands a remarkable fossil bone from the Chalk of Cuxton. Its horizon is probably the *Rhynchonella cuvieri*-zone, and it was obtained from the pit worked by Messrs. Weekes and Trechmann (see p. 486). I am unable to speak definitely of the affinities of this specimen, yet

it seems to me very probable that it will prove to belong to the Rhynchocephalia, that remarkable group of lizard-like animals which includes the living New Zealand Tuatera or Hatteria [6]*, and the Triassic *Hyperodapedon* [7, 8] I have ventured to give a short account of this bone in order that other workers may be on the look-out for additional specimens which may give a further clue to its true systematic position.

This bone, which is represented one and a half times natural size in figure A, below, is 44 mm. long, 7·5 mm. wide at the broadest part, and not more than 4 mm. thick. It is still attached to the matrix, which is a hard, greyish chalk. One side of the bone is nearly straight, and forms a sharp edge; the opposite side is curved and thick, so that the bone tapers away towards both



DENTIGEROUS BONE FROM THE MIDDLE CHALK OF CUXTON. A × $\frac{3}{2}$; B, Middle Portion, × 3.

extremities, one end being narrower than the other. The thick edge shows a deep depression, extending from near the middle of the specimen to the narrower extremity (*a*, *a*), which is evidently the articulation for another bone.

The surface of this specimen, which still adheres to the matrix, is concave from end to end, while that which is exposed is convex in the same direction and occupied by three or four longitudinal rows of conical tooth-like nodules. A series of comparatively large nodules runs parallel with, and close to, the straight margin. The nodules are best shown towards the narrow end of the bone, being much denuded (probably by attrition during life) at the broader end. A second row of smaller nodules runs parallel with, but is separated by a distinct groove from, the larger one, and like it extends from end to end of the bone. A third row of small nodules occupies the middle third of the convex side of the bone, and three or four nodules are to be seen on the extreme margin.

* The figures in brackets (6) refer to the list of works at the end of this Appendix.

At both extremities the nodules are denuded, but this is especially the case at the broader end where, for nearly half the length of the specimen, the nodules are almost obliterated.

When examined with a lens this denudation is found to consist for the most part of small parallel grooves, generally in sets of three or four together, but the grooves in different sets are variously orientated, and are found upon most of the nodules, with the exception of a few in the middle of the bone.

There is little doubt that these nodules are teeth, for although so intimately connected with the supporting bone as to show no line of demarcation, yet in this respect they are like the teeth of *Hyperodapedon* [7, 8] and *Sphenodon* [6]. Judging from the form of the specimen it is probably either a palatine or a pterygoid bone.

It is by no means clear whether the denudation of the teeth took place during the life of the creature, and was due to the crushing of some hard substance taken as food, or whether it is to be attributed to some post-mortem cause.

The close resemblance between these teeth and those of *Hyperodapedon* is very striking, and leads me to think that the specimen will eventually be found to be related to the Rhynchocephalia, although a comparison with the known forms of these creatures throws no further light upon the nature of this specimen.

In Hatteria [6] (*Sphenodon punctatus*) the living representative of the Rhynchocephalia, there are, in the upper jaw on each side, two rows of teeth attached to the maxilla and palatine bones, between these two rows there is a groove into which bites the single row of teeth supported by the ramus of the lower jaw. The longitudinal groove in the Chalk specimen bears some resemblance to that of *Sphenodon*; but in the latter the groove is between the teeth of two distinct bones (the maxilla and palatine) while in the former it appears to run along the middle of a single bone.

The species of *Hyperodapedon* [7, 8, 9] from Elgin, Devonshire, and India have each several rows of teeth in the upper jaw, and these are nodular, peculiarly facetted, and worn into a groove by attrition with the lower jaw. The specimens hitherto met with have the teeth on each side of the upper jaw attached to what appears to be a single bone, and in this respect, therefore, resemble the Chalk fossil; this bone, however, is believed to be the united maxilla and palatine bones. Moreover, in all the examples of *Hyperodapedon*, the bone in question is very solid and strong, while the Chalk bone is thin and slender. *Rhynchosaurus* [11, 8], having a more slender head than *Hyperodapedon*, may perhaps have a palate more resembling Mr. Dibley's specimen; but the known examples of the upper jaws and palate have the teeth too much obscured to allow of comparison. For similar reasons no satisfactory comparison can be made with *Homœosaurus*

and other small Jurassic genera [1, 10], which are included in the Rhynchocephalia.

The Eocene and Cretaceous genus *Champsosaurus* of Cope [2, 3, 4, 5], although related to the Rhynchocephalia has a very different type of dentition. The skull and snout are much elongated; the teeth of the maxilla are long and slender, and all the bones of the palate bear small conical teeth, generally in several rows; but these teeth are quite unlike those of the Chalk specimen.

While calling attention to these various forms, I am fully aware, as I have already stated, that there are no sufficient grounds to justify a certain reference of this Chalk fossil even to the group of the Rhynchocephalia; but at the same time the peculiarities of the teeth apparently find their nearest counterparts in this group, and it seems to me probable that the bone is a palatine or pterygoid of some such an animal as Hatteria or *Rhynchosaurus.*

The possibility of this bone belonging to a fish has been considered, but I am not acquainted with any piscine form of teeth which might indicate a closer relationship than that which seems to exist between this bone and the Rhynchocephalia.

At present Mr. Dibley's specimen is a puzzle, but in the hope that by publication the problem may be solved, I have ventured to bring this notice of the fossil before the readers of the PROCEEDINGS.

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EXCURSION TO EASTBOURNE AND SEAFORD.

MAY 26th, 1900.

Director: C. DAVIES SHERBORN.

Excursion Secretary: A. K. COOMARA-SWAMY, F.G.S.

(*Report by* THE DIRECTOR.)

SEVERAL members, who had arrived at Eastbourne the night before, met the Director at the Wish Tower at 9.30 a.m. The party proceeded to the shore at Gore pit, and walking on the *Holaster subglobosus*-zone, collected from the zone of *Actinocamax-plenus*, an easily traced bed of blue marl varying from 10 to 15 or more feet thick. At Holywell the *A. plenus* marls were seen to sink into the shore, and the section here exposed passes through the whole of the *Rhynchonella cuvieri* beds and a great part of the zone of *Terebratulina gracilis*. Meeting the official party at òne o'clock, at Cow Gap, the Rev. W. R. Andrews and Mr. Whitaker explained the nature of the beds below the White Chalk at this point, pointing out the dome of Upper Greensand and Chloritic Marl and the curious confusion on the shore, resulting in an alternation of Gault and Upper Greensand, the result of either a thrust from seawards or of the landslip landwards. Resuming the walk, the Director pointed out the various zones of the White Chalk between this point and Birling Gap, at which point the party divided; the majority returned to Eastbourne, but the Director and a few members proceeded over the top of the Seven Sisters to Seaford. At the top of the last of the Sisters, the Director found and showed plates of *Uintacrinus*.

The following day Mr. Sherborn conducted an unofficial excursion round Seaford Head, showing *Marsupites* and *Uintacrinus* plates at the top and at the base of Seaford Head, the grand exposure of the *M. cor-testudinarium*-zone, and the *Actinocamax-quadratus*-zone. On this occasion the party were so fortunate as to find two specimens of *Terebratulina rowei* in the lower part of the *quadratus*-zone, a specimen of *Actinocamax merceyi* some fifty feet above the *Marsupite*-band, and to trace the variation of the *Echinocoridæ* in their passage upwards from the *Uintacrinus*-band to the lower part of the *Actinocamax quadratus*-zone, for although the cliffs were much sea-worn many fossils were to be seen in section.

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EXCURSION TO BOXMOOR.

SATURDAY, MAY 12TH, 1900.

Director: UPFIELD GREEN, F.G.S.

Excursion Secretary: A. K. COOMARA-SWAMY, F.G.S.

THE Geologists left Euston Station by the 12.25 p.m. train, and on arrival at Boxmoor walked to Bennet's End, Hemel Hempstead,

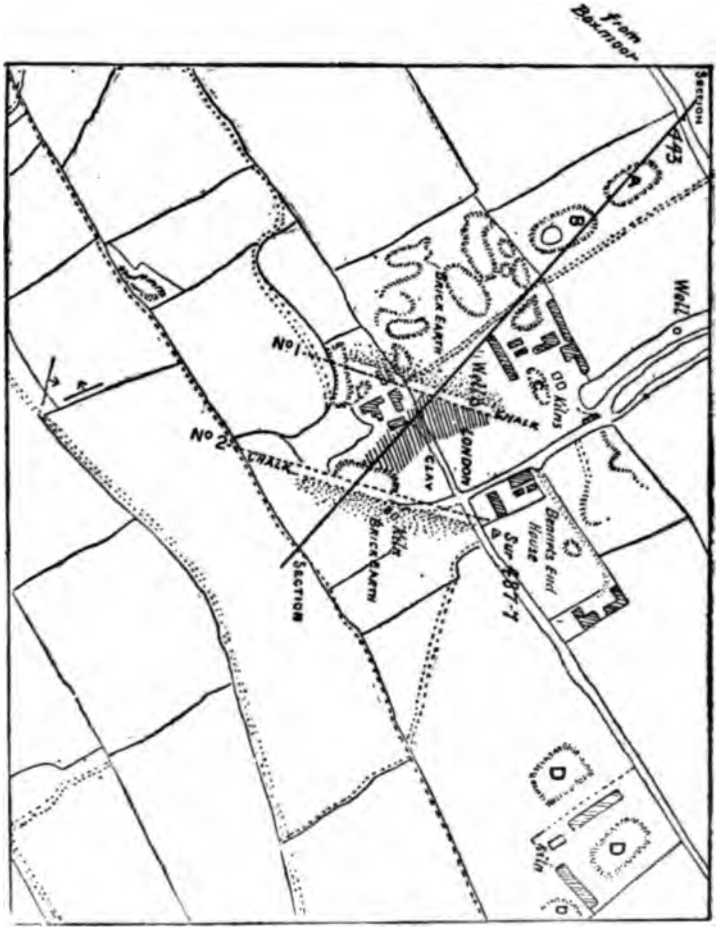

FIG. 1.—PLAN OF BENNET'S END BRICKFIELDS.
Scale: 9 inches=1 mile.
(Figs. 1 and 2 reprinted from the *Trans. Herts. Nat. Hist. Soc.*, vol. vi, plate v).

in order to examine some sections of Lower London Tertiaries and brick-earths.

There are two pits situate on a plateau at about 450 ft. O.D.

The more northerly pit (A on plan), is worked for brick-earth chiefly, and shows a section of about 20 ft. of brownish clay with a few pebbles, overlying a bluish-grey clay with many pebbles.

In the pit marked B, from five to six feet of gravel, containing large pebbles of quartzite and sandstone, with blocks of sarsen-stone and rolled fragments of pudding-stone, are seen resting on a reddish brick-earth (a little more sandy than that seen in pit A) laminated, and traversed by veins of pipe-clay. From twenty to twenty-five feet of this brick-earth had been dug down to a boss of chalk. Such bosses of chalk, covered with green-coated, rolled and un-rolled flints, are frequently met with in this district, sometimes in the brick-earth and occasionally projecting into the gravel.

South-eastward of the above-mentioned pits, along the line No. 1 on plan, occurs a ridge of chalk, its eastern side sloping at an angle of 75°-80°. The surface of the slope is hard, polished, striated, and covered with a layer of black clay. Against this "wall" of chalk rests, horizontally, a bluish-grey plastic clay, part of the Reading Series, surmounted by about 12 ft. of the Basement Bed of the London Clay containing characteristic fossils, teeth of *Lamna*, etc.

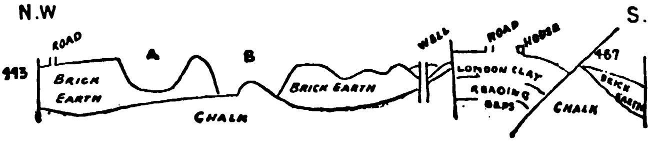

FIG. 2.—SECTION AT BENNET'S END BRICKFIELDS.

Scale: 9 inches=1 mile; vertical scale exaggerated.

An old pit in the rear of Tilekiln Farm, described by Mr. Whitaker,* was next visited, where 12 ft. of the Basement Bed of the London Clay, with Reading Beds below, abut against a wall of chalk. The direction of the fault and its inclination will be seen on reference to No. 2 on the accompanying plan and section.

A cordial vote of thanks to the Director, genially acknowledged, concluded a most interesting excursion.

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UPFIELD GREEN.—*Proc. Herts. Nat. Hist. Soc.*, vol. vi, 1892, p. lxii.

* "Geology of London," vol. i, 1889, p. 208.

EXCURSION TO MALVERN AND DISTRICT.

WHITSUNTIDE, JUNE 2ND TO JUNE 5TH, 1900.

Director: PROF. THEODORE T. GROOM, M.A., D.SC., F.G.S.

Excursion Secretary: A. C. YOUNG, F.C.S.

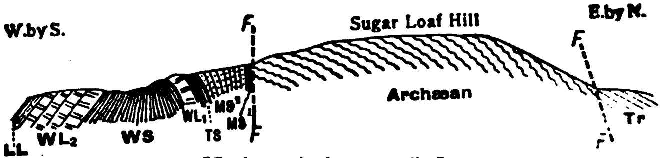
(*Report by* THE DIRECTOR.)

Saturday, June 2nd.—The excursion commenced with a walk along the eastern side of North Hill to the large quarry above Malvern Link. The faulted and slickensided undulating surface of the Archæan massif was seen to be admirably exposed, and showed in places a coating of fault-breccia composed chiefly of irregular pieces of Archæan rock set in a reddish paste of Triassic material. The Archæan itself here, it was pointed out, consisted chiefly of diorite with intrusive veins of granite. The latter rock seemed to have very thoroughly penetrated and mingled with the former, a process resulting in the production of a rock of thoroughly mixed character. Many hand specimens were obtained showing the most intimate inter-penetration of the two ingredients.

Passing up the depression containing the covered reservoir of the Malvern waterworks, similar close relations between the aplite and a variety (hornblendite) of the diorite, consisting largely of hornblende, were observed in loose blocks which had fallen down the slopes.

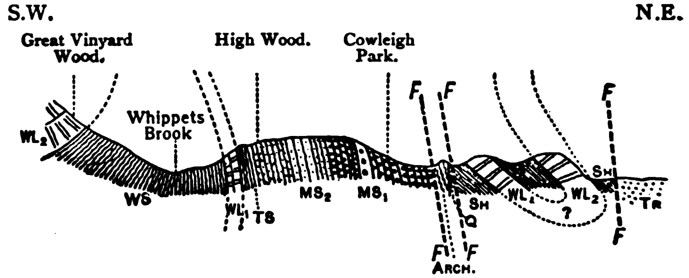
At the top of the hill the haze precluded enjoyment of the whole of the wide panorama to be seen from this point, but during the descent to West Malvern the chief features of the picturesque country to the west were admirably seen. The May Hill Sandstone formed the slope in the immediate foreground. The Woolhope Limestone at or near the foot of this slope formed no very marked feature, but the Wenlock and Lower Ludlow Shales formed vales on either side of the gently rising escarpment of Wenlock Limestone, while the Aymestry Limestone with its peculiar S-like curve rose up into a sharper ridge beyond; and after dipping down beneath the Old Red Sandstone syncline of Colwall, reappeared again as a fine escarpment near Ledbury.

The party next proceeded to the line of the great western fault bounding the Archæan, and fine blocks of Miss Phillips' conglomerate with *Stricklandinia* and *Lindströmia* were discovered behind the houses west of Sugar Loaf Hill. It was here pointed out that although many of the fragments in the conglomerate closely resembled those of the adjacent hills, the latter were probably buried by the conglomerate, and a considerable proportion of the pebbles must have come from some neighbouring



[Scale: 3 inches=1 mile.]

FIG. 1.—SECTION ACROSS THE MALVERN RANGE IMMEDIATELY NORTH OF THE DINGLE.



[Horizontal scale: 3 inches=1 mile.]

FIG. 2.—SECTION ACROSS COWLEIGH PARK AND HIGH WOOD.

TR. Trias.
SH. Wenlock, or Lower Ludlow Shale.
WL_2. Wenlock Limestone.
WS. Wenlock Shale.
WL_1. Woolhope Limestone.
TS. Tarannon Shale.
MS_2. Upper Beds of May Hill Sandstone.
MS_1. Lower Beds of May Hill Sandstone.
Q. Cambrian Quartzite.
Arch. Archæan.
FF. Faults.

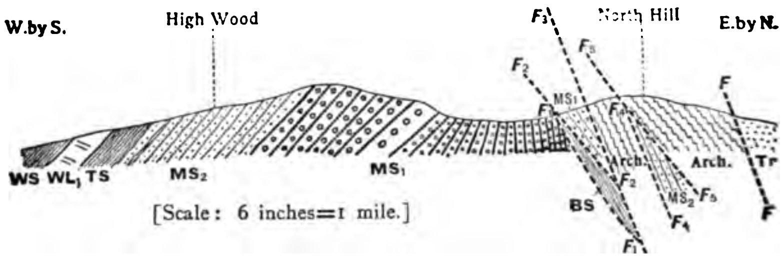


FIG. 3.—SECTION ACROSS HIGH WOOD AND NORTH HILL.

Tr. Trias.
WS. Wenlock Shale.
WL_1. Woolhope Limestone.
TS. Tarannon Shale.
MS_2. Upper Beds of May Hill Sandstone.
MS_1. Lower Beds of May Hill Sandstone.
BS. Black Shales.
Arch. Archæan.
FF. Faults.

(Figs. 1—7 reprinted, by permission, from the Quarterly Journal of the Geological Society, vols. lv. and lvi.)

source. In the quarries on each side of the Dingle, or the depression between Sugar Loaf Hill (the south-western elevation of North Hill) and the Worcestershire Beacon, the May Hill beds, imperfectly revealed, were seen resting against the Archæan.

In the quarry above, complex relations between the diorite and aplite were again seen. Here the aplite appeared to have been intruded into the previously foliated diorite, and both rocks to have been sheared by subsequent movements.

The day's work was completed by a visit to the May Hill conglomerates and the Archæan of Cowleigh Park. Specimens were collected from the presumed Cambrian quartzite, which was found, after a short search, almost covered with vegetation.

On *Monday, June 4th*, about fifty of the party drove from Great Malvern along the eastern side of the range to the Gullet Pass (between Swinyard and Midsummer Hills). On the way attention was drawn to the sharply defined eastern boundary of the hills, and to the peculiar way in which the cwms end at their faulted junction with the Trias.

In the quarry at the southern end of Swinyard Hill the structure termed "plagioclinal" by Dr. Callaway was discussed, and the view was maintained that in pre-Cambrian times the western midlands were occupied by an old mountain land, the folds of which ran more or less transversely to the trend of the present Malvern Hills, and that denudation had levelled the tract, which later became a sea-floor, the component rocks of which, striking across the meridian, had been covered unconformably by the Cambrian sediments. The Archæan core of the present Malverns might be regarded as a part of this old floor, thrust up in Carboniferous times and then denuded.

In a small quarry higher up the Gullet Pass the small faulted strip of Hollybush quartzite and conglomerate was seen, and specimens of *Kutorgina phillipsii*, Holl., and an *Obolella* were collected. Many pebbles of metamorphic quartzite, pink granophyre, variously tinted rhyolites, etc., were obtained from the conglomeritic layers, and it was argued that though these materials bore a general resemblance to certain rocks of the present Malverns, the balance of evidence indicated derivation from some other source.

After lunching at the quarry the party proceeded to the ancient camp at the top of Midsummer Hill, whence a magnificent view of the surrounding country rewarded the climbers; the Clee Hills, the Lickey, the Cotswolds, May Hill, the Forest of Dean, and many of the distant Welsh mountains being visible.

On the descent of the central depression of the hill, marking the shattered infold of Cambrian and Silurian rocks, lack of time prevented an extended search for débris of these rocks, but fragments were picked up on the way, and the May Hill Sandstone was seen *in situ* in the Hollybush Pass.

[Scale: 6 inches = 1 mile.]

FIG. 4.—SECTION ACROSS THE SOUTHERN PART OF RAGGEDSTONE HILL.

p'p'. Fault between Archæan and Trias
pp Faults
t Trias
k. May Hill Beds.
j Upper Gray Shales.
i. Coal Hill igneous band.
h. Lower Gray Shales.
g. Igneous band at the base of the Gray Shales.
f. Upper Black Shales.
e. White-leaved Oak igneous band.
d. Lower Black Shales.
c. Hollybush Sandstone.
b. Hollybush Conglomerate.
a. Archæan.

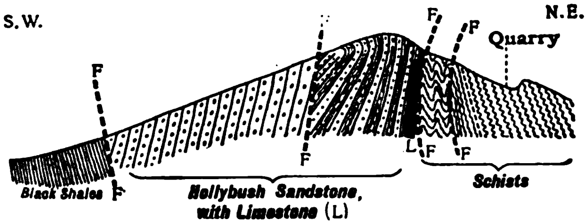
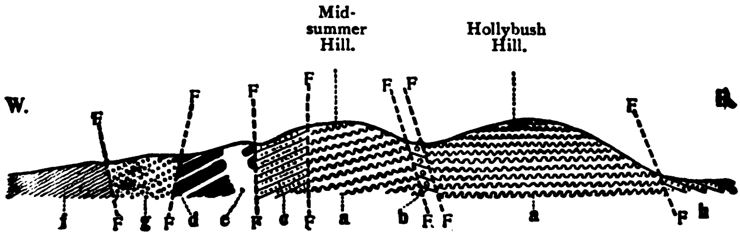


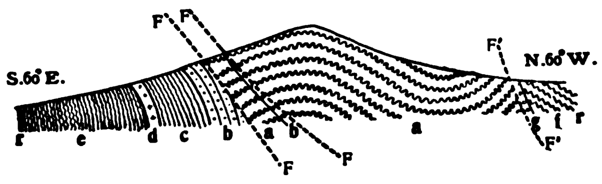
FIG. 5.—SECTION ACROSS THE SOUTH-WESTERN PART OF RAGGEDSTONE HILL.



[Scale: 4½ inches=1 mile.]

FIG. 6.—SECTION ACROSS MIDSUMMER AND HOLLYBUSH HILLS.

FF. Faults.
h. Trias.
g. May Hill Sandstone.
f. Grey Shales (Cambrian).
e. Igneous rocks in Black Shales.
d. Black Shales (Cambrian).
c. Hollybush Sandstone.
b. Hollybush Quartzite.
a. Archæan.



[Scale: 4½ inches=1 mile.]

FIG. 7.—SECTION OF THE RANGE ALONG THE LINE OF THE MALVERN TUNNEL.

rr. Railway level.
F'F'. Fault between Trias and Archæan.
FF. Faults.
g. Breccia.
f. Trias.
e. Wenlock Shale.
d. Woolhope Limestone.
c. Tarannon Shales.
b. May Hill Sandstone.
a. Archæan.

Crossing the dyke in the Hollybush Sandstone, on the northern slope of the Raggedstone, the party proceeded to the picturesque district of White-leaved Oak. Here the chief features of the area of Cambrian rocks were pointed out, and examples of *Sphærophthalmus alatus*, Bœck, and *Ctenopyge bisulcata*, Phil., etc., were collected by many of the party from the inverted black Upper Cambrian shales, but the small size of the exposures and their overgrown condition made the discovery of fossils a matter of some difficulty.

Owing to the lateness of the hour a short time only could be devoted to the large quarry close to the village, but the junction of the Hollybush Sandstone and Archæan was examined before returning to Hollybush. Afterwards a visit was paid to the dyke in the Hollybush Sandstone at the south-western corner of Midsummer Hill.

On *Tuesday, June 5th*, train was taken to Ledbury, where, after walking over the broken anticline of Ludlow rocks, an examination was made of the Lower Ludlow Shales at the eastern end of the tunnel. Many fossils, including Trilobites, Orthoceratites, Brachiopods, and Corals were collected.

The party then, retracing their steps, visited a quarry in the Aymestry Limestone, the high westerly inclination of which, like that of the passage beds from the Silurian into the Old Red Sandstone, illustrated the steep nature of the western side of the small anticlines in this district.

At the station, owing to a recent cutting back of the western end of the tunnel, the Ledbury Shales (passage beds) were once more well revealed, and fine specimens of *Lingula* were obtained from a green band at the eastern end of the cutting. The same bed showed a striking example of soil-creep. After lunching in the cutting, train was taken to Colwall, where at the western end of the tunnel the Old Red Sandstone was seen faulted against the Wenlock Shale. The latter formed an excellent collecting ground, and the following fossils, with many others, were obtained: *Plasmopora petalliformis*, Lonsd., *Palæocyclus rugosus*, E. and H., *Pentamerus linguifer*, Sow., *Orthis rigida*, Dav., *Echinoencrinus armatus*, Forbes, *Pisocrinus pillula*, De Kon. and *Phacops downingiæ*, Murch.

Upon leaving the cutting those members not obliged to return home that day, concluded the day's work by a visit to the Upper Ludlow Shales south of the station, where many characteristic fossils were obtained.

On *Wednesday, June 6th*, starting from Ledbury Station by brake, the Association paid a second visit to the southern Malvern district. After passing through the picturesque old town of Ledbury, and through the wooded district of Eastnor, a halt was made to examine the olivine-diabase between Bronsil Lodge and Fowlet Farm. At the latter place the party, leaving the brake, proceeded

to Coal Hill Cottage, where numerous sills of diabase were seen intercalated in the *Dictyonema*-shales. On the way to Howler's Heath a recent cutting away of the turf, at the northern end of an igneous boss south of Coal Hill, had exposed the *Dictyonema*-shales dipping in a south-easterly direction, and apparently indicating the existence of one or more dislocations hitherto undetected in the locality.

At Howler's Heath the May Hill Grits and Sandstones, and the Haffield Breccia were examined, and after lunch a careful search in the grey shales at the southern termination of Chase End Hill resulted in the discovery of several specimens of *Dictyonema sociale*, Salt., a fossil now less easily obtained than formerly at this locality. In a cottage garden immediately east of Coal Hill the *Dictyonema*-shales with sills of diabase were seen, like the same beds a little farther south-east, to dip towards the hill.

Proceeding across the basaltic ridges through White-leaved Oak, the party walked to the northern extremity of Chase End Hill, where excavations made with the aid of a pick revealed the oldest black shales yet detected in the Malvern district, and numerous fragments of the peculiar dark grits interbedded with these shales were unearthed. In the shales themselves specimens of a form allied to *Beyrichia angelini*, Barr., were obtained.

The same species has been obtained by Prof. Lapworth in the Stockingford Shales. In England, as in Scandinavia, the *Beyrichias* are found beneath the zone of *Sphærophthalmus* and its associates. Many fragments of the shale were carried away to be split at leisure; some of these subsequently furnished interesting specimens of a new variety of *Acrotreta*.

On the way back to Hollybush a few specimens of *Hyalithus* (*Serpulites*) *fistula*, Holl., were collected from débris of the grey Hollybush Sandstone at the north-western corner of Raggedstone Hill.

Tea was provided at Hollybush, and then the party returned by brake to Ledbury, where time was found to visit the old church.

On *Thursday*, *June 7th*, train was taken to Colwall, and a walk of about a mile brought the party to Upper Colwall, where the inverted Wenlock Shale, Woolhope Limestone, and May Hill Sandstone were seen in some excellent road exposures. Numerous beautiful corals in the position of growth were detected in the limestone, and specimens of *Stricklandinia lens*, Sow., *Dinobolus davidsoni*, Salt., and branching fucoids were obtained from débris of the May Hill Sandstone. A sharp shower drove the party to take shelter in Mr. Wickham's house, where the opportunity was taken of examining his fine Silurian fossils.

Quarries showing the superposition of oolitic Wenlock Limestone on Wenlock Shale were next visited. After collecting specimens and lunching, the party proceeded down the dip-slope of the

Wenlock Limestone to the Purlieu Lane, at the lower end of which the Upper Ludlow beds with the usual fossils were seen to be overlain by the Downton Sandstone, the two being probably connected by transitional beds, though a small interruption in the section prevents this being seen. From a carbonaceous layer in the sandstone numerous imperfect specimens of *Pachytheca* were collected.

It had been intended to examine the Silurian beds farther north during the afternoon, but rain set in so heavily that a return was made to Colwall, where the excursion concluded.

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EXCURSION TO CATERHAM, GODSTONE, AND TILBURSTOW.

SATURDAY, JUNE 16TH, 1900.

Director: W. WHITAKER, F.R.S. (PRESIDENT).

Excursion Secretary: A. C. YOUNG, F.C.S.

THE Geologists left London Bridge Station (S.E.R.) at 9.30, for Caterham. They walked southward to the crest of the Chalk escarpment at Upwood Scrubs, where a mass of the Blackheath Pebble Beds overlying the Chalk was examined, and a fine

view over the Lower Greensand tract obtained. The walk was continued along a footpath down the escarpment to Godstone Quarry, in Upper Greensand (firestone, etc.). The underground workings, down the dip northward, were noted and their many recorded water-levels at varying heights were alluded to; but work was going on that prevented the members from seeing these. Instead of this, however, some old workings near Quarry Farm were visited, and then a new working about a third of a mile eastward, where a good section was seen.

The members proceeded thence across the outcrop of the Gault along the road to Godstone, stopping at the northern part of the village, to see a sand-pit in the Folkestone Beds. This was formerly carried on as an underground working (for the lower bed of sand), but has now been opened up, the upper bed of sand being also worked. The walk was then continued, through the village of Godstone, to the pits of Tilburstow, which are more than a third of a mile long, and made simply to get the chert at the bottom for road-metal. A very large area has been worked over the tract to the east, now a plantation. At one part a little of the Folkestone Beds (sand) is touched. The whole of the Sandgate Beds is passed through (clayey and with green sand). The chert is classed with the Hythe Beds by the Geological Survey. A fine landslip was seen in part of the pit. The excursion was continued eastward by way of a cutting on the road down Tilburstow Hill in the sands of the Hythe Beds, to the faulted mass in which the chert-beds are again shown on the western side of the road.

The return journey was made down the dip-slope of Tilburstow Common (Hythe Beds), across the fields to Tandridge, and through Tandridge Park (dip-slope of the Folkestone Beds) to Oxted, a walk that gave constant opportunities of seeing the beautiful and varied scenery of the Lower Greensand of Surrey.

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EXCURSION TO GUILDFORD.

SATURDAY, JUNE 23RD, 1900.

Director: A. K. COOMARA-SWAMY, F.G.S.

Excursion Secretary: A. C. YOUNG, F.C.S

(*Report by* THE DIRECTOR.)

THE party reached Guildford at 2.20, and proceeded, by kind permission of Mr. Mitchell, to the more westerly of the Guildford Park Potteries pits. The section is chiefly in mottled clay, but on the north side this is overlain by a brown shelly bed, with *Cyrena*, *Ostrea*, and *Melania inquinata*. This shelly bed is evidently the same as that mentioned by Mr. Whitaker as forming the top of the Woolwich and Reading Series in the railway cutting. The section visited is the most westerly exposure of the shelly beds. The lower mottled clay contains some concretions of the nature of "race," remarkable for their very large size and irregular forms.

Analyses of the "race" made by Mr. A. C. Young give the following percentages:

Carbonate of lime	64·5
Clay	17·5
Very fine sand	18·0

Crossing Guildford Gap the large quarries in Quarry Street were visited; in these the Upper and Middle Chalk are well exposed. In the upper pit the former is very massive. In the lower pit (Middle Chalk), Mr. Whitaker called attention to the fibrous markings found in the chalk, and said that they probably represented pseudomorphs of calcite after aragonite, and were not of the nature of slickensides.

Taking the field path to the Chantries, and thus crossing the Upper Greensand and Gault, the Folkestone Beds of the Lower Greensand were seen in a small quarry opened on the north slope of the Chantries; and a few yards farther on the party turned north again up the short lane leading to the Warren Farm Quarry. An exposure of Upper Greensand chert was noticed in the lane. The quarry itself shows grey chalk and Chalk Marl, much shattered and inclined at a very high angle, the disturbance being due to a local fault. The long narrow quarry seems to follow the strike of the beds. *Pecten beaveri* and *Ammonites rhotomagensis* were found.

Crossing the Chantries by kind permission of the proprietor, the escarpment made by the Bargate Stone was reached, and from this position a fine view was obtained of the Lower Greensand district and the Weald beyond. The Director pointed out

the Peasemarsh anticline, which soon dies away to the east, and the wide outcrop of Atherfield Clay in the East Shalford district.

The party descended the slope and visited the brickyard near the railway. Here a few feet of Atherfield Clay is seen to be overlain by Drift. In this district the lower part of the Atherfield Clay contains a band of very fossiliferous nodules. These are not seen in the brickyard, but a few were obtained from the bed of the Tillingbourne, near by, and exhibited to the members. *Thetis minor*, Sow., *Arca raulini*, Leym, *Perna*, and many other fossils could be seen in them.

The party then returned to Guildford, where tea was obtained. In the station yard a vote of thanks was accorded to the Director, who replied, and the party returned to town by the 7.41 train.

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EXCURSION TO SILCHESTER.

Saturday, June 30th, 1900.

Director: J. H. Blake, Assoc.M.Inst.C.E., F.G.S.

Excursion Secretary: A. C. Young, F.G.S.

(*Report by* The Director.)

The members assembled at Reading Station at 12.49 p.m., and proceeded to the Reading Museum and examined the Romano-British collection from Silchester. Mr. Colyer, the assistant-curator, pointed out many of the most interesting relics, amongst them being a considerable number of Roman silver and bronze coins, ranging from B.C. 39 to A.D. 423. After a vote of thanks to Mr. Colyer, proposed by the President, the members returned to the station and entrained for Mortimer, where they arrived about 2 p.m. They then walked nearly two miles in a south-westerly direction to a projecting spur of plateau-gravel westward of Brocas Land Farm, where a fine view of the surrounding country was obtained. The Director briefly explained the

geological structure of the district, and stated that the plateau-gravel (Southern Drift) rested upon Lower Bagshot Beds overlying London Clay. But what he particularly drew attention to, and wished to impress upon them, was the large amount of denudation that had taken place since the deposition of the plateau-gravels. These occupied all the highest ground in the district, and often occurred as isolated patches on outliers of the Bagshot Beds, one of which he pointed out three-quarters of a mile to the east of Silchester, where the plateau-gravel was at the same level as that at Silchester, namely, 300 ft. above sea-level, with a valley intervening more than 100 ft. in depth.

The members, who were here joined by the cyclists with Mr. Monckton, then resumed their walk. During their descent into the valley separating them from Silchester, attention was drawn to an exposure of Lower Bagshot Beds in the road-cutting; and to the junction of the Bagshot Beds with the London Clay on the opposite side of the valley, where a spring was thrown out.

On arrival at the Amphitheatre, Mr. Mill Stephenson—in charge of the Silchester excavations for the Society of Antiquaries—conducted the party first into the Amphitheatre, then to the north wall of the Roman city, and afterwards through the Manor Farm to where the excavations were in progress, south-east of the North Gate. Here the foundations of houses were exposed, with tesselated pavements and mosaic floors, hypocausts, etc., and rubbish-pits (about 6 ft. in depth) from which so many relics had been obtained. Four special excavations had been made by Mr. Mill Stephenson to show the junction of the plateau-gravel with the underlying Lower Bagshot Beds. The deepest well that had been explored was 32 ft. in depth. After an inspection of the relics that had been found this year, the Forum (now much grown over) was visited and described by Mr. Mill Stephenson.

Leaving the City by the West Gate, the members proceeded to a large gravel-pit on Silchester Common, which showed a section 6 ft. in thickness, of pebbly and subangular flint-gravel, characteristic both in constituents and thickness of the plateau-gravel (Southern Drift) of this district.

Called upon by the President to give views as to the gravel before them, Mr. Monckton remarked that they were on a plateau a little more than 300 ft. above the sea, capped with what he had termed the Silchester type of Southern Drift.* He looked upon all these gravels as river-gravels, the composition depending upon the various rocks to be found in the drainage-area of the various streams. This gravel contained no Lower Greensand débris and no Bunter pebbles, and was evidently deposited by a river draining a Chalk and Tertiary country, much the same as the present Kennet-Loddon drainage-area.

* *Quart. Journ. Geol. Soc.*, vol. xlviii, 1892 (Map on p. 38).

The next gravel-capped plateaux to the east, Spencerwood Common, Heckfield Heath, etc., were capped by gravel containing an abundance of fragments from the Hythe Beds of the Lower Greensand, and may perhaps be looked upon as gravel of an old edition of the River Blackwater. The present Blackwater does not, however, drain any Lower Greensand country; it is separated from the nearest outcrop of that formation by the River Wey, and the speaker suggested that these gravels show that the Blackwater used to have a great drainage area to the south or south-east which has now been acquired by the River Wey, just as much old Thames drainage-area has been acquired by the River Severn.

The débris of the Hythe Beds, so abundant in the gravel of Spencerwood Common, has not only been brought across the present course of the Wey, but also across the present course of the Loddon, and this looks as though the Blackwater used to join the Loddon a little farther west than now. Mr. Monckton suggested that Spencerwood Common was very probably the actual point of junction of the two streams.

The Director then exhibited the new Geological Survey Maps of the district, one with Drift and the other without, and explained how very different from the present the conditions and physical features of the country must have been when the extensive spreads of plateau-gravels were deposited. He also referred to the distribution of the Northern Drift, characterised by its numerous large rounded quartzites, in contradistinction to that of the Southern Drift, which did not contain any. Pointing to the hills visible in the distance, he stated they were the abrupt uprise of the Chalk on the south side of the London Basin.

Tea was partaken of at the Crown Inn, when a cordial vote of thanks, proposed by the President, was accorded to the Director, to Mr. Mill Stephenson, and to the Society of Antiquaries.

The party returned by a different route to Mortimer Station, and in Wall Lane inspected another section (6 ft. in thickness) of plateau-gravel, which, though a continuation of the same spread of gravel, showed a much more stratified appearance than that in the pit on Silchester Common.

Reading was reached at 7.15 p.m., when some of the members visited the Abbey ruins and Forbury Gardens before leaving by the 8.20 p.m. train.

After tea those members who had brought cycles accompanied Mr. Monckton to Heckfield Heath, where they visited a pit in what he called old Blackwater gravel, now 270 feet above the sea. The abundance of fragments from the Hythe Beds was noticed.

Mr. Monckton remarked that other flats occur at lower levels

and illustrate the remarks as to step terraces which he made at Kingston Hill on April 28th (see p. 444). He considered that these flats marked pauses in the process of elevation of the land. The gravel at Heckfield was seen to be much more clearly stratified than that at Silchester Common.

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EXCURSION TO KETTERING AND THRAPSTON.

SATURDAY, JULY 7TH, 1900.

Directors: PROF. J. F. BLAKE, M.A. AND BEEBY THOMPSON, F.G.S.

Excursion Secretary: W. P. D. STEBBING.

(*Report by* J. F. BLAKE.)

THE party from London met some of the members from Northampton, including one of the Directors, at Kettering Station, whence they walked to the brickyard on the Thrapston Road. Here is seen an apparent junction of the upper beds of the Lias with the overlying Northampton Sands, or Ironstone; but it was pointed out by Mr. Thompson that the upper hard beds were wont to slip over the soft unctuous clay, particularly on the slopes of hills, and that in all probability some of the highest beds of the Lias, here really existing, were thus concealed. He pointed out, some ten feet below the apparent summit, a line of white weathering nodules, often coated with encrusting organisms as though they had long lain exposed on the sea bottom, above which there was a different fauna to that in the beds below—a fact easily verified by the members. Hence he regarded this line as the palæontological summit of the Lias proper, the beds above being the *A. Jurensis*-beds, which are continued into the base of the ironstone.

From this brickyard the members had a walk of about four miles

to Cranford St. John, where, after lunch they examined a deserted quarry in the Great Oolite limestone. It was here pointed out that we were crossing the Lower Oolites on the line of their feeblest development. The whole of the Inferior Oolite is represented by a few feet of Northampton Ironstone, and a few more of Estuarine beds, the Upper and Lower divisions here becoming one continuous series, on account of the absence of the Lincolnshire Limestone, which only commences a little north of this. The Great Oolite itself here consists also of a few comparatively thin beds, and they are consequently crowded with fossils, of which the members made a good collection. These included a *Terebratula* very like *T. intermedia*, and a *Rhynchonella* considered by Mr. J. F. Walker to be new.

From this point exposures were numerous, large and good. One newly worked showed both divisions of the Estuarines lying on the Ironstone in a rather disturbed manner, and another about 3 miles from Thrapston, on the south side of the road, showed the complete succession of Ironstone (just seen), Estuarine, Oolite, and Oolite clay (just seen).

The next working was an exceptionally fine one of the Cornbrash, which it was the primary object of the excursion to see. Here was exposed a very long section showing at the top Boulder Clay, to a large extent derived from the neighbouring Oxford Clay. Next came most characteristic Cornbrash in several bands, all highly fossiliferous, about 5 feet. Then about 12 feet of blue-black clay called Great Oolite clay, and at the base 11 feet of Great Oolite limestone, for which the opening is made. The members of the party had thus been able to see during the day the junctions of the five divisions of the rocks between the Lias and the Oxford Clay, and to verify the thickness of four of these divisions. The spoil heaps, in which the Cornbrash fossils are unmixed with those of the Oolite, being thrown in a different place, provided a good harvest of fossils to collectors.

This working is opposite the Islip iron furnaces, a little more than a mile from Thrapston, whither the members then adjourned for tea, after which some few were able to see the old Thrapston workings close to the Midland Railway Station whence so many Polyzoa have been obtained, and the party finally took train *viâ* Kettering to London.

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EXCURSION TO PURLEY, KENLEY, AND WHYTELEAFE.

SATURDAY, JULY 14TH, 1900.

Directors: THE PRESIDENT AND G. E. DIBLEY, F.G.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by* G. E. DIBLEY.)

THE members arrived at Purley Oaks Station at 2.20 p.m., and proceeded to Haling Pit. The Director stated that the chalk is worked in the base of the *Micraster cor-anguinum*-zone, as described in the PROCEEDINGS, vol. xvi, p. 490, and referred to the absence of fossils characteristic of the upper part of the zone.

The large pits at Purley Junction were next visited, where the lithological character of the Chalk which marks the zone of *Micraster cor-testudinarium* in the London area was noted. Near Purley Station the President drew attention to some large, rounded masses of Woolwich and Reading conglomerate or "pudding stone," and stated that they are a prominent feature in the Caterham Valley; they extend as far as Croydon and could be traced in the various gravel-pits along the course of the Croydon Bourne, from the Kenley Waterworks to Purley Station.

At Kenley several fossils were procured from the Rose and Crown pit, including *Terebratulina striata* and a *Nautilus* in addition to the characteristic zone-fossils. Tea was very kindly provided by the Rev. T. Griffiths, M.A.. Votes of thanks, proposed by the President and Mr. E. T. Newton to Mr. and Mrs. Griffiths for their repeated acts of kindness to the Association, were accorded by acclamation.

After a vote of thanks to the Director had been duly acknowledged, a move was made to the Whyteleafe Lime Works, where the characteristic fossils of the zone of *Terebratulina gracilis* were obtained.

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EXCURSION TO WINCHFIELD AND HOOK.

SATURDAY, JULY 21ST, 1900.

Directors: P. L. SCLATER, Ph.D., F.R.S., and H. W. MONCKTON, V.P.G.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by* H. W. MONCKTON.)

THE party assembled at Hook Station and walked eastwards along the main line of the London and South Western Railway to Winchfield.

For the first $1\frac{1}{4}$ miles the railway is carried on an embankment, the country being London Clay and the Alluvium of the Whitewater. A little south of the line there is the extensive gravel-flat of Bartley Heath. The gravel consists of material from the Chalk country to the south. The level is 247 ft. above the sea.

Shortly after crossing the Whitewater, the Bagshots come in and cause a rise of the ground, the embankment giving place to a shallow cutting.* A halt was made at a place where a bridge crosses the line, and the Directors gave an account of the geography and geology of the district. It was explained that the object of the excursion was to visit the fine section at Shapley Heath, made for the purpose of widening the line. The section was on the south of the railway.

Mr. Monckton remarked that the section extended from the Barton Beds (Upper Bagshot), of which there were some 15 ft., through the whole of the Bracklesham (Middle Bagshot), into the Bagshot (Lower Bagshot). He drew a comparison between it and other railway cuttings which had passed through the same formations, and in particular Goldsworthy, described by Prestwich in 1847 (*Q. J. G. S.*, vol. iii, p. 382). The cutting on the Ascot-Bagshot line described by Mr. W. H. Herries, in 1881 (*Geol. Mag.*, April, 1881), and that near Wellington College on the South Eastern Railway described by himself in 1883. (*Q. J. G. S.*, vol. xxxix, p. 350).

Proceeding along the line the light-coloured current-bedded sand of the Bagshots was seen at the western end of the Shapley Heath Cutting. Above it were laminated clays, forming, as Mr. Monckton said, the bottom of the Bracklesham—the junction being well seen. There had been, he added, some discussion as to the exact point at which the division between Bracklesham and

* *Note.*—The bottom of the Bagshot Beds is not seen to the east of Hook, but it is well shown in the cutting on the west of the station. The top of the London Clay is sandy.—H. W. M., Sept. 26th, 1900.

Bagshot (*i.e.*, between Middle and Lower Bagshot), should be drawn, but the importance of that separation had been much reduced by the discovery of abundant casts of marine shells some 20 ft. down in the yellow sands of the Bagshot (Lower Bagshot), at Woking. These laminated clays are very constant at the bottom of the Bracklesham (Middle Bagshot), and form the lower of the two brick-clays of that Series in the district.

Some part of the cutting had been sloped at the time of the excursion, but Mr. Clement Reid, F.R.S., who saw that part when fresh, had kindly furnished the following note:—

"A well at the western end of this cutting was sunk 28 feet into the Bagshot Sand, *i.e.*, about 25 feet below the level of the rails.

"Exactly opposite the western edge of Oldman Copse the cutting is shallow and shows:

		Feet.
BRACKLESHAM	Laminated light-coloured (weathered) and carbonaceous loams	10
BAGSHOT .	Fine white, much false-bedded, sand with clay-pebbles (dug to below rail-level)	17

"On the west side of Shapley Tunnel, the upper part of the cutting shows gravel resting irregularly on buff and yellow loamy sand. In the middle of this cutting the gravel is thin and the section is:

	Feet.
Gravel	thin
Brown and yellow loam	15
Laminated blue sandy loam	18
Glauconitic greensand	—

"About 100 yards east of Shapley Tunnel [now removed and replaced by a bridge], a landslip showed white sand overlying the dark-grey sandy laminated loam, which occupies the lower 20 feet of the cutting. Above this sand were more loams like those exposed farther east. At the top of the cutting there is a little gravel.

"On the west side of the Winchfield Station bridge, the green loam becomes darker, and as the cutting deepens westward sandy loams come on above to a thickness of about 25 feet. Still following the beds westward, the lower deposits become unweathered and greener."

Mr. Monckton drew special attention to the green bed which occurs with great constancy between the brick-making clays, and is the fossiliferous bed in this district.

The characteristic shells usually were *Cardita planicosta*, Lam., and *Corbula gallica*, Lam., but neither of them had been found here, and the only mollusca found were casts of a spiral shell, probably a *Turritella*. A considerable collection of fish remains was found, and the following have been kindly determined by Mr. E. T. Newton, F.R.S.

FISH FROM SHAPLEY HEATH, WINCHFIELD, BRACKLESHAM SERIES (MIDDLE BAGSHOT).

Teeth.

Odontaspis macrota, Ag. (3 specimens).
„ *elegans*, Ag. (2 specimens).
„ *cuspidata*, Ag. (3 specimens).
„ *acutissima*, Ag. (1 specimen).
Lamna vincenti, Winkl. (3 specimens).
Galeocerdo minor, Ag. (2 specimens).
Ætobatis or *Myliobatis* (probably both) (8 specimens).

Vertebræ.

Teleostean vertebræ (2 specimens).

Fin Spine.

Cœlorhynchus rectus, Ag. (1 specimen).

Also eight specimens of teeth of *Odontaspis*, not well enough preserved for the species to be determined.

Ascending the cutting at the bridge, Dr. Sclater led the way to the top of the hill, 319 ft. O.D., from which a very fine view was obtained. He drew attention to the chief features of the country, and in particular to the Tertiary outliers at Horsedown Common and Well. At the former spot the Reading Beds are capped by London Clay, which rises to a height of over 500 ft. above the sea.

Returning to the railway the members descended the side of the cutting on the east of the bridge, and Mr. Monckton explained his version of the succession.

There was a cap of gravel (Southern Drift) mainly flints, but with a few fragments from the Hythe Beds. Then there were about 15 ft. of yellow sand with a pebble-bed at the bottom—Barton (Upper Bagshot). The top of the Bracklesham (Middle Bagshot) was clayey, and in it were several irregular lines of pebbles. Below there was a light-coloured sand with laminæ of whitish clay; in some places the sand and in others the clay predominating. Then there was a well-marked water-line, the top of a dark-coloured clayey bed. The above beds, with a thickness of about 20 ft., forming the upper brick-making beds of the Bracklesham of this district. The green bed, with fossils, probably occurs at the bottom of the cutting, but was hidden by slips at the time of the excursion.

After completing their examination of the cutting, the members walked to the Beauclerk Arms Hotel, where tea was provided. After tea, on the motion of the President, a vote of thanks to the Directors was passed, and a vote of thanks was also accorded to the Representative of the London and South-Western Railway,

who had kindly accompanied the party during the afternoon, and had given much assistance and information.

After tea a visit was paid to a brickfield on the west of the road, a little south of Winchfield Station, where the Bracklesham clays are worked, and this concluded the work of the afternoon.

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EXCURSION TO THE RAILWAY CUTTING SOUTH OF GROVE PARK STATION, S.E.R.

SATURDAY, JULY 28TH, 1900.

Director: T. V. HOLMES, F.G.S.

Excursion Secretary: A. C. YOUNG, F.C.S.

(*Report by* THE DIRECTOR.)

THE object of this excursion was to visit the cutting north of the tunnel between Grove Park and Chiselhurst stations on the S.E.R. main line.

Alighting at Grove Park Station, the party entered the cutting, permission having been obtained for that purpose. Before descending to examine the details, the Director made a few general remarks on the slight amount and varying direction of the dip of the beds within a radius of a mile or two from the spot on which they were standing. In the cutting, the dip, he said, coincided so perfectly in direction with that of the line thence to Grove Park Station, that the section given by Mr. Whitaker of the eastern side as seen in 1865, showed accurately what could now be seen on the western. (See Whitaker, "Geology of London," etc., vol. i, 1889, p. 226, Fig. 41.) But while the dip where they were standing was to the north-west, close to and west of the entrance of the tunnel it became southerly; and in Rockpit Wood, at the southern, or Chiselhurst, end of the tunnel, the dip was northerly. As to the details of the Tertiary beds in the immediate neighbourhood, the fullest information was that furnished by a boring at the new workhouse at Grove Park, the details of which had been kindly sent to him by Mr. T. Dinwiddy, architect of the buildings. This borehole was made between Dec. 20th, 1898, and Jan. 21st, 1899.

BOREHOLE AT NEW WORKHOUSE, GROVE PARK.

		Thickness. ft.	in.	Depth. ft.	in.
Deposit made by a small brook.	Subsoil	2	0		
	Ballast	3	0		
	London Clay	13	0	18	0
Oldhaven Beds? 22 ft.	Black pebbles and water	2	0		
	Clay and shells	1	0		
	Green sand and water	7	0		
	Hard shells	2	0		
	Green blowing sand	10	0	40	0
Woolwich and Reading Beds? 47 ft.	Clay and shells	3	0		
	Blowing sand and water	6	0		
	Clay and shells	2	0		
	Very hard clay and shells	9	0		
	Coloured clay	10	0		
	Green sand, pebbles, and water ...	10	0		
	Black sand, pebbles, and water ...	7	0	87	0
Thanet Sand 53 ft.	Very hard grey sand, rock, and water	8	0		
	Live grey sand and water	45	0	140	0
	Flints...	2	0		
	Into chalk...	101	0	243	0

Entering the cutting towards its northern end, where the London Clay only could be seen, the party made its way southwards towards the mouth of the tunnel. Between the northern end of the cutting and the bridge nearer the tunnel (by which a road crosses the railway) the London Clay, with a pebble band from 8in. to 18in. thick at its base, and a few feet of Oldhaven sand with scattered pebbles at the bottom of the cutting, were very clearly seen. Under the bridge the pebbly base of the Oldhaven Beds, containing shells, appeared. A few yards south of the bridge the outcrop of the London Clay with its basement bed was well exposed. On coming to the cutting west of the mouth of the tunnel, it was found that there the London Clay, with a pebble band at its base about 3ft. thick, was again visible, the dip being very slight in amount, but southerly in direction. There is, therefore, either a roll over of the beds or a fault between the bridge and the mouth of the tunnel.

At one spot north of the bridge a little patch of false-bedded sand appeared in the London Clay near its base. Crystals of selenite were abundant in the London Clay. In Mr. Whitaker's section of the more easterly side of this cutting, two small but sharp turns in the basement pebble-bed of the London Clay may be seen. The section being clearer than in 1865, these two sharp turns appeared to be two small reversed faults dislocating the pebble-bed to the extent of a foot or perhaps a trifle more, their course not being traceable in the clay above or in the sand below. After examining the beautifully clear sections the party dispersed.

EXCURSION TO NETLEY HEATH AND NEWLANDS CORNER.

SATURDAY, AUGUST 11TH, 1900.

Director: W. P. D. STEBBING, F G.S.

Excursion Secretary: H. A. HINTON, B.SC., F.G.S.

(*Report by* THE DIRECTOR.)

THE chief object of the excursion was to examine the gravel, sands, and ironstone at Netley Heath, to prove the fossiliferous character of the ironstone and to show the similarity of the beds to those occurring at points farther eastward on the North Downs.

The party assembled at Gomshall Station, and walked by way of Colekitchen Farm to Netley Heath, traversing the outcrop of the Gault and Upper Greensand.

A fine section in the Folkestone Beds was seen outside the station, and another section at the top of these sands was examined; also road sections in the Gault, Upper Greensand, and base of the Middle Chalk were noted in passing.

Netley Heath consists of a tract of ground with a northerly slope, mainly covered with heather. The sands and ironstones are shown by a red colour on Sheet 8 of the Geological Survey Map, and extend from a level of about 600 feet O.D. almost at the top of the North Downs (as at Headley Heath) to a level of about 570 feet O.D.

This patch of sand and ironstone forms one of a series which is found along the top of the North Downs from Netley Heath to Paddlesworth, north of Folkestone. The fossiliferous pipes at Lenham, range from 500 to 620 feet O.D., and the sands on Headley Heath occur at 628 feet O.D. But although of a far more recent age than the Eocene outliers, which are often in close proximity, these sands occur at much the same level or even below them. This is undoubtedly due to their porous nature, which allows water to pass through and dissolve the chalk below.

The attention of geologists was first drawn to this series by Prestwich in 1857 (*Quart. Journ. Geol. Soc.*, vol. xiv, p. 322), and details of all the patches will be found in our President's Memoir on the London Basin (Whitaker, *Mem. Geol. Survey*, vol. iv, 1872, pp. 339–342).

As early as 1854 fossils were found in one of these patches at Lenham, in Kent, but their evidence as to the age of the sands was considered doubtful, although Prestwich assigned them to the Crag. In 1886 Mr. Clement Reid made a careful investigation of the deposit at Lenham and its fossils, and satisfactorily proved the deposit to be of Pliocene age (*Nature*,

vol. xxxiv, p. 341). A full account of Mr. Reid's work will be found in his Memoir on the Pliocene Deposits of Great Britain, 1890 (*Mem. Geol. Survey*). At page 48 he remarks: "Westward, towards Merstham and Guildford, some of the outliers mapped by the Survey may really be Pliocene as suggested by Prof. Prestwich, but at present there is such an entire absence of positive evidence in favour of this view that it is needless to describe them."

This sentence is quoted to show the great interest which attaches to the imperfect fossils found now apparently for the first time at Netley Heath. The patch in which they are found is not mapped as Eocene or Pliocene, but as of doubtful age. The fossils are in the form of casts in af erruginous sandy grit with occasional flint pebbles. The grit much resembles the ferruginous sandstone of the Folkestone Beds, but the presence of the flint pebbles is sufficient distinction.

Fragments of fossils referable to the genera *Modiola*, and possibly *Cyprina*, were found by members during the excursion, and fragments of *Nassa*, *Trochus*, *Cardium*, *Pectunculus*, *Tellina*, and *Thracia* have since been found, but in such a poor state of preservation that they cannot be specifically determined. These genera indicate beds of a marine origin, and although they do not enable us to correlate these deposits with those at Lenham with certainty, I am inclined to think that the beds will prove to be of the same age. All the above genera except *Modiola* have been found at Lenham, where, on the visit of the Geologists' Association in 1892, 31 species of fossils belonging to 27 genera were obtained.

It was remarked by members who had visited Lenham, that the mode of occurence of the fossils and the appearance of the matrix greatly resemble the conditions obtaining at Lenham.

The following sections were visited:

1. A sand-pit on the east of a road from Gomshall to East Horsley, showing about 10 feet of yellow and bleached sand; above the sand are some patches of mottled clay and gravel consisting almost wholly of rolled fragments of chert and ironstone from the Lower Greensand. Level, about 570 feet.
2. A small pit about 5 feet deep, at a level of rather over 600 feet; the section shows highly ferruginous yellow sand with a few small pebbles and much concretionary iron ore, with chert and patches of rolled flints above. The fossils came from this pit.
3. A sand-pit half-a-mile west of the first pit, showing about 12 feet of yellow sand with a few small pebbles, and in one place a patch of small pebbles above the sand. Level about 600 feet.

There is a fourth section on the Heath rather lower than the others, which was not visited. This pit contains a mixture of

sand and rolled flints of all sizes, and is exactly similar to one seen on Headley Heath in 1895, at about the same level.

The Director remarked that the difference in these three sections on Netley Heath is surprising considering their short distance apart; but if we suppose that they were formed on a submerged reef away from the coast line—which is Mr. Reid's theory—those portions of the reef near the sea-level would be most affected by the action of the sea, which would prevent shells from accumulating on those portions, and which would have a rounding action upon any loose stones; a state of things which might explain section 1.

Leaving Netley Heath, the members followed the track along the top of the North Downs to Newlands Corner, and visited the extensive gravel workings there at about 500 feet O.D. The gravel, which otherwise is similar to that which occurs in most of the sections on Headley Heath, is characterised by the large size of the flints of which it is chiefly composed. Mr. Monckton's explanation of it is that it is probably a very old river gravel, but no doubt newer than the sands and ironstone of Netley Heath.

Leaving these sections, the party made their way to Chilworth for tea. After the Director's reply to a most cordial vote of thanks, the geologists returned by the 7.56 train to London.

REFERENCES.

Geelogical Survey Map, Sheet 8 (Drift Edition).

Oidnance Survey Map, New Series, Sheet 285, 1s.

1862. W. WHITAKER.—"On the Western End of the London Basin, etc.," *Quart. Journ. Geol. Soc.*, vol. xviii, p. 273.

1887. H. H. FRENCH.—"Excursion to Gomshall, Netley Heath and Clandon," *Proc. Geol. Assoc.*, vol. x, p. 182.

LONG EXCURSION TO KESWICK.

MONDAY, AUGUST 20th, to SATURDAY, AUGUST 25th, 1900.

Director: JOHN E. MARR, M.A., F.R.S., F.G.S.

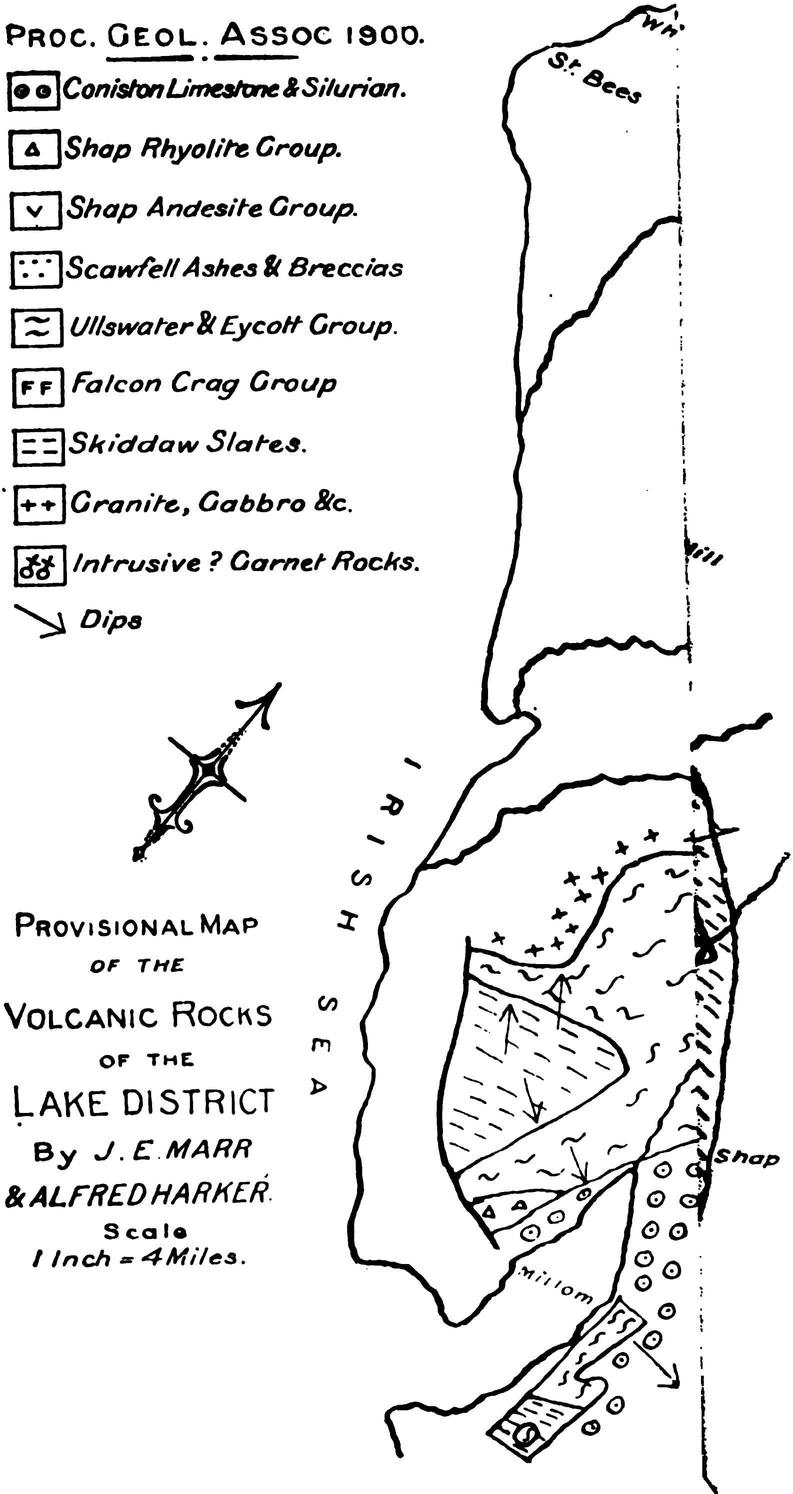
Excursion Secretary: FREDERICK MEESON.

(*Report by* THE DIRECTOR.)

[PLATES XIII, XIV.]

BETWEEN fifty and sixty members of the Association and their friends assembled at Keswick, making the Park Hotel their headquarters. In addition to the official programme, unofficial excursions were conducted on days preceding and succeeding those announced in the official circular, under the leadership of Mr. J. Postlethwaite, F.G.S.

Monday, August 20th.—The day was mainly devoted to an examination of the characters of the Falcon Crag and Bleaberry



To face page 527.]

Fell group of volcanic rocks. Passing beneath the base of Castle Head, formed of diabase, which Mr. Clifton Ward looked upon as possibly occupying the neck of one of the old volcanoes, the first halt was made in a cutting of purple breccia in the road beneath Falcon Crag. The Director explained that this occurred between the Skiddaw Slates and volcanic rocks, and stated that he and Mr. Harker were disposed to regard it as a crush-breccia, though the evidence, which was not solely derived from the rocks of that section, was not quite convincing. The terraced outline of Falcon Crag and the adjoining Fell was noticed from this point, and explained as due to the alternation of hard lavas and softer ashes, which lay nearly horizontally, and which had not undergone much alteration.

The party left the high road somewhat farther on, and walked to Ashness Bridge, where the contrast between the smooth, peaked hills of Skiddaw Slates and the rough, craggy eminences of the volcanic rocks was pointed out, as also the nature of the delta separating Derwentwater from Bassenthwaite, and of the islands (which are little drumlins) of the former lake.

Lodore was next visited, and the compact lava with platy jointing just beyond the fall inspected. The members of the excursion were interested in the marks of glaciation about Grange Bridge, especially by the excellent roche moutonnée of Skiddaw Slate on the left bank of the river.

The junction of Skiddaw Slate and volcanic rock on the hillside above Hollow's Farm was next visited, and a member of the party succeeded in obtaining a specimen of the two rocks welded together. The general impression appeared to be that the junction of the two series at this spot was truly conformable.

On returning to the high road, the crushed "rain-spot" breccias of Quay Foot Quarry were inspected, as also the remarkably folded and cleaved vesicular lavas and ashes by the roadside to the north of the Rosthwaite alluvial flat, and an accumulation of drift on glaciated rock near the same place (see Plate XIV, fig. 2).

On arriving at Rosthwaite the party drove back to Keswick.

Tuesday, August 21st.—Most of the members left Keswick by the 9.40 train, arriving at Threlkeld about ten a.m. They were there joined by Mr. Harkowitz, the proprietor of the Threlkeld Quarry, who conducted them to the quarry and explained the processes involved in the formation of concrete paving-stones from the refuse of the micro-granite. The large quarry was then visited, and the character of the micro-granite studied. The remarkably even jointing of the rock, simulating stratification, was duly noted, but the inclusions in the micro-granite afforded the chief interest to the members. Inclusions of Skiddaw Slate and of volcanic rocks (the latter containing garnets in places) were

collected, and also specimens of garnet in the micro-granite itself. The latter, it was suggested, might have been derived from the volcanic rocks. A large inclusion of Skiddaw Slate was seen in one part of the quarry; this did not appear to have undergone much alteration.

On leaving the quarry, the process of forming setts by hand was seen. The President proposed a hearty vote of thanks to Mr. Harkowitz, the proprietor, for his courtesy in admitting them to the quarry, and for conducting them over it, and also to his foreman, Mr. Bragg, for assistance. This was carried by acclamation, and Mr. Harkowitz briefly replied, and expressed his pleasure at having been the means of affording the members a chance of viewing the works.

The rest of the party reached Threlkeld shortly before noon, and a move was then made up the Glenderaterra valley, where the effects of metamorphism of the Skiddaw granite on the Skiddaw Slates was studied. Members first passed over normal Skiddaw Slate, and halted for lunch by a waterfall in the stream north-east of the Blencathara Lead Mine, where they examined the chiastolite slates; a move was then made to Roughten Gill, where the spotted andalusite slates were found, and then to Sinen Gill, where the granite was studied, and the mica slates, in the innermost zone of metamorphism, were found in contact with the granite, at its summit. One member found a pegmatite vein in the granite at this point.

The party separated here, some returning to Keswick over the summit of Skiddaw, others by the slopes of Lonscale Fell, while the rest walked to Threlkeld Station, in time to avoid a thunderstorm accompanied by heavy rain.

Wednesday, August 22nd.—The members drove from the Park Hotel at 9.30, and alighted at Seathwaite, which, as they had occasion to learn by actual demonstration, is noted for its rainfall. In walking up to Sty Head Tarn, they saw good moraine mounds between the hamlet and Stockley Bridge, and on the slopes above Stockley Bridge studied the garnet-bearing rocks which are here fully developed, and formed by alternation of breccias and lava-like rocks with a "streaky" flow-like structure. The question as to whether these were contemporaneous or intrusive was discussed, and the prevailing opinion seemed to be that they were in this locality truly contemporaneous. The remarkable structures in the banded ashes above Sty Head Tarn were examined, and the characters of Sty Head, Sprinkling, and High House Tarns, and of several gullies, including Peers Gill on Lingmell, were noted. Owing to the rain, it was felt advisable to return by Sty Head instead of proceeding down Grainsgill, and excellent scenic effects were observed in spite of (or rather owing to) the rain. Some of the members ascended Scawfell Pikes, and experienced another thunderstorm.

Thursday, August 23rd.—As the morning opened with heavy rain, the Director met the party at the Keswick Museum, and gave a demonstration, with the assistance of the late Mr. Clifton Ward's maps, and of the well-known relief model of the district. Shortly after eleven the weather cleared, and a number of the members started in char-a-bancs for Honister Pass. Two well-marked terminal moraines were seen in the valley above Seatoller and an interesting case of diversion of drainage due to the operation of the "law of unequal slopes" was observed at the top of the pass. Here a number of rivulets course down the cirque-like termination of the valley, but the two northerly ones have been captured by the streams draining into Buttermere, which has sawn through the ridge, causing the deflection of drainage, and giving rise to the marked cliff of Honister Crag.

The slates of Honister Crag were noticed, and the drive resumed for Buttermere, where the Honister party was joined at lunch at the Buttermere Hotel by another section, who had driven direct to Buttermere through the Vale of Newlands.

After lunch boats were taken across Crummock to Scale Force. The shingle spit connecting Low Ling Crag with the mainland was pointed out, near the landing-place, and also the position of the main lava here mapped by Clifton Ward as interstratified with the Skiddaw Slates. At Scale Force, the party hammered the granophyre, and saw that the position of the Force was originally determined by the superposition of the laccolitic mass of granophyre on the softer Skiddaw Slates. The now familiar thunderstorm was experienced when returning in the boats. The members eventually drove back to Keswick by the Vale of Newlands.

Friday, August 24th.—At 9.30 the members of the excursion drove to Rosthwaite, and thence walked up the Langstrath Valley, as far as Blea Crag. On leaving Rosthwaite, the Director pointed to a moraine which started from the ridge near Stonethwaite Church, and eventually became plastered against the rocks of Rosthwaite, giving rise to an alluvial flat, and probable diversion of drainage. Beyond Stonethwaite, the Ullswater lavas were tapped near Galleny Force, and the garnetiferous rocks, resembling those of the Sty Head path, to the south of this. The Director drew attention to cases of diversion of drainage by glacial interference. The first case he characterised as doubtful, the second and third as less so, and the fourth, which he had already described in the *Geographical Magazine*, as the most convincing. It was noted that the stream, when passing over the hard garnetiferous rocks in the second and third cases, had scarcely cut any channel, but that in the fourth case a well-defined gorge was cut through the softer and well-jointed banded ashes which there exist. The Director called attention to the miniatures of small rock-basins in these banded ashes, owing to the weathering influence of vegetation on gently-sloping rock surfaces; he also pointed out some

admirable potholes at the upper end of the gorge. One of the members discovered a peg-like process at the bottom of the pothole, in its centre, surrounded by a ring-like depression, proving very satisfactorily the effect of the gyration of pebbles in forming the hole.

The intrusive garnet-bearing rocks of Blea Crag were next examined, and Mr. E. E. Walker, B.A., who is occupied with their study, explained what he had learned about them.

Most of the members returned to Stonethwaite by the west side of the valley, as the bridge over Greenup had been carried away by a flood in 1898, of which the members had seen the traces, near Stonethwaite, earlier in the day.

The top of an extensive mass of garnet rock, seen in contact with banded ashes, was visited on the east side of the valley, nearly opposite Stonethwaite Church, and the members then returned in carriages from Rosthwaite.

In the evening, after dinner, the President read a letter which the Director had received from Mr. W. H. Hudleston, F.R.S., who was one of the Directors of the previous excursion of the Association to Lakeland, nineteen years ago, and the members now present requested the President to send a cordial message to Mr. Hudleston, on their behalf. He then proposed a vote of thanks to the Director, and also to Mr. Postlethwaite, who had kindly conducted excursions.

These gentlemen briefly replied, and acknowledged the vote.

Mr. Teall, President of the Geological Society, proposed a vote of thanks to Mr. Meeson, to whose care in making arrangements the success of the excursion was so largely due. Mr. Meeson replied.

Saturday, August 25th.—The members started for the last excursion in heavy rain, but fortunately, before the train had reached Troutbeck Station, the weather cleared, and remained fine during the day. From Troutbeck Station they drove to Patterdale, and visited the Slate Quarries near the head of Ullswater. The Director explained that the slate at that spot was in the Scawfell Ash Group, and was brought down to that low level from the upper slopes of Helvellyn, by a thrust fault ranging through the Grizedale Valley.

Some of the physiographical features of the region were pointed out, and the party then made its way to the landing-pier and took steamer down the lake. On board the steamer, the Director showed how the outcrop of the junction between the Skiddaw Slates and volcanic rocks was only explicable on the hypothesis of a fault having a fissure which was nearly horizontal. The isolated patch of volcanic rock resting on the Skiddaw Slates opposite Howtown was specially noticeable, and also the inclination of the divisional planes of separation of the different

members of the volcanic rocks, and their abutment against the fault-plane.

At Pooley Bridge the Old Red Conglomerates were studied. The Director gave a sketch of the history of previous opinions concerning this rock, after which Mr. R. D. Oldham, Superintendent of the Geological Survey of India, directed attention to its resemblance to sub-aërial torrential accumulations formed in regions of general dryness, such as are found in Baloochistan and other parts of Central Asia. (See Pl. XIV, fig. 1.)

The party returned by coach to Penrith, and thence by train to Keswick.

On the following day some members of the Association drove round Thirlmere. At the King's Head, Thirlspot, a small contingent left the others, and made the ascent of Helvellyn, and at the Nag's Head, Wythburn, Mr. Marr led the President, ex-President, and a few others over the fell to Watendlath, and thence to Keswick. These studied the Armboth Dyke and some rocks occurring in a crush-belt above Watendlath Tarn.

August 27th.—Mr. Marr accompanied some of the members of the Association to Waterhead, Windermere, by coach. From Waterhead a move was made to Skelgill, where the Coniston Limestone and the various zones of the Skelgill graptolitic shales were pointed out. Most of the party returned to Keswick, but one or two walked to Windermere Station and made a cursory inspection of the beds of the Upper Slates from the Coniston Flags to the Bannisdale Slates.

ERRATUM.—A mistake was unfortunately made in drawing Fig. 2 (p. 466). The Bed 2 on the west side of the fault should be about $\frac{1}{2}$ mile farther south. The positions of the beds are correctly stated in the text. J. E. M.

LONG EXCURSION (*continued*).

SUPPLEMENTARY EXCURSION TO CAUSEWAY FOOT.

ON the *19th of August*, 1900, a party of twenty-one, under the leadership of MR. JOHN POSTLETHWAITE, F.G.S., walked to the Vale of Naddle. On the way, charming views of Derwentwater and the valley of the Derwent were obtained.

The leader of the party drew attention to a number of boulders perched upon the eastern end of Skiddaw, more than 1,200 feet above sea-level, and pointed out the line of junction of the Skiddaw Slates and the Volcanic Series. Near Causeway Farm the junction was examined in detail. The soft, shaly con-

dition of the uppermost bed of Skiddaw Slate was noted. The lowest member of the Volcanic Series is here seen to be a light-grey, compact lava, about 150 feet in thickness, and is overlain by a lava much darker in colour and more crystalline in structure. The western mass of the St. John's quartz-felsite next received attention. Afterwards the members returned to Keswick.

SUPPLEMENTARY EXCURSION TO EYCOTT HILL AND THRELKELD MINE.

MONDAY, AUGUST 27TH, 1900.

THE members remaining in the Lake District visited Eycott Hill and Threlkeld Mine under the leadership of MR. JOHN POSTLETHWAITE, F.G.S.

They proceeded by train to Troutbeck, and walked thence to Eycott Hill, where two exposures of enstatitic lava were inspected. Leaving this interesting section, shortly after mid-day, they paid a visit to the Threlkeld Mine, where, through the kindness of Captain Bawden, they were able to examine the process of dressing the ore (containing galena and blende), and to collect specimens from the rough material as it is taken out of the mine. There are two veins, one bearing 10° E. of N., the other bearing 25° W. of N., the veins running together in the northern part of the mine. This mine has been worked northward into the chiastolite slate.

EXCURSION TO STROOD AND HALLING.

SATURDAY, SEPTEMBER 8TH, 1900.

Director: G. E. DIBLEY, F.G.S.

Excursion Secretary: H. A. HINTON, B.Sc.

(*Report by* THE DIRECTOR.)

THE members arrived by the 10.45 a.m. train, and walked to the pits known as "The Quarry." (All the pits visited during the excursion are described in the PROCEEDINGS, vol. xvi, pp. 484-487, so that no detailed account of them is necessary here). A large upper valve, with part of the lower valve, of *Inoceramus volutus* was seen, and the Director obtained an undescribed *Pecten*.

From this pit the members walked to Messrs. Martin & Earle's pits, and thence to Messrs. Booth's pit, where fossils characteristic of the zone of *Holaster planus* were obtained. Afterwards, by the kind permission of the Manager, Mr. Craske, the members

FIG. 1.—OLD RED CONGLOMERATE, POOLEY BRIDGE, ULLSWATER.

FIG. 2.—DRIFT ON GLACIATED ROCK NORTH OF ROSTHWAITE.
(From photographs by A. K. Coomara-Swamy, F.G.S.).

[To face page 332.]

were conducted over the cement factory by the foreman, Mr. Usborne, who described the process of the cement manufacture. A vote of thanks was accorded the Manager and Mr. Usborne for their kindness.

Messrs. Hilton & Anderson's pits at Halling, in the zones of *Rhynchonella cuvieri*, *Actinocamax plenus*, and *Holaster subglobosus* were next examined.

The next pits visited were those of Messrs. Lee & Co., at Holborough, the finest exposures of chalk on the west side of the Medway. The *Actinocamax plenus*-marls here form a very conspicuous feature in the upper part of the lower pits. A large number of typical fossils were at the disposal of the members.

After tea at the Bull Hotel, Snodland, a cordial vote of thanks to the Director was proposed by Mr. Sherborn, and carried unanimously.

REFERENCES.

Geological Survey Map, Sheet 6.
Ordnance Survey Map, New Series, Sheet 272. 1s.

1872. WHITAKER, W.—"Geology of London Basin." *Mem. Geol. Survey*, vol. iv.

1887. WOODWARD, H. B.—"Geology of England and Wales."

EXCURSION TO ORPINGTON,

SATURDAY, SEPTEMBER 22ND, 1900

Director: T. V. HOLMES, F.G.S.

Excursion Secretary: A. C. YOUNG, F.C.S.

(*Report by* THE DIRECTOR.)

THE object of this excursion was to see the Tertiary sections now exposed, between Chiselhurst and Orpington, on the S.E.R. main line, which is being widened.

The party, numbering more than forty, assembled at Orpington Station and proceeded northward towards Chiselhurst. A few yards south of the station bare Chalk is visible, but at the northern end of it a fine clear section of Thanet Sand, capped by a few feet of greenish-looking Woolwich Beds, appeared. Unfortunately it was impossible to examine the Woolwich Beds otherwise than by means of such fragments as had fallen down. Before leaving the precincts of the station, the Director called attention to the slight anticlinal and synclinal folds between Orpington and the cutting south of Grove Park. Between Orpington and Chiselhurst there is a slight synclinal fold. Then at Chiselhurst a slight anticline causes the appearance of the Chalk and Thanet Sand there. At the southern end of the Sundridge tunnel the dip is northerly, and, at the northern end, southerly, the tunnel

being consequently through a synclinal fold. On July 22nd it was evident that a slight anticlinal fold existed between the mouth of the tunnel, where the dip was southerly, and the beds northward of the bridge crossing the line a few yards away, which had a steady north-westerly dip towards Grove Park Station.

Proceeding northward, the party noticed Thanet Sand on the more westerly side of the line, where it is being widened, to a point a little beyond the spot at which the footpath crosses the railway. Thence, little worth noting could be seen until the north-western corner of Clay Wood was reached, and there a small siding showed the shell beds of the Woolwich Series to a thickness of 6 feet. The shells were mainly Cyrenas. Between this point and Town Court Farm there was a sectionless interval. But in the cutting which begins a few yards south of Towncourt Wood, London Clay appeared, containing many of the calcareous concretions known as "race." London Clay was also seen in the cutting on the north-western border of Towncourt Wood. There being no sections thence to Chiselhurst, the party separated at the northern end of the cutting.

The President kindly assisted in the elucidation of doubtful points, and distributed proofs of p. 135, vol. i, of his Memoir on "The Geology of London and of part of the Thames Valley," (1889), in which the results of visits to the Orpington Cutting many years ago are given. As the Memoir in question, though valuable, is by no means portable, and as the sections between Orpington and Chiselhurst may retain their clearness, and possibly develop rather than deteriorate during the next few months, it may be useful to give here all that refers to the scene of our Excursion:

"The cutting on the South Eastern (Lewisham and Tunbridge) Railway at Orpington Station must have given a fine section when clear. When I saw it first the greater part was unfinished, and when again, in 1870, the sides were overgrown; however the following succession could be made out:

Sand of the Oldhaven Beds, at the highest part.

Woolwich Beds {
- Clay.
- Shelly clay, with peaty earth at bottom.
- Clay.
- Pebbly green sand.

Thanet Sand, cut into from the end near the Station up to as far as the footpath across the line.

"The lines of growth on the sides of the cutting show distinct and even bedding, dipping at a small angle along the line N.W.

"Mr. E. Nash has published the following details of the beds shown in part of this cutting,* and he tells me that his notes were taken at about 300 or 400 feet from the Orpington end, that is to

* "Pre-Adamite London," pp. 30, 31, 8vo, London, 1879.

say, south-west of the highest part, and beyond the on-coming of the Oldhaven Beds.

		Feet.
Woolwich Beds.	Vegetable clay earth	[? about 11.]
	Yellow clay	
	Yellowish earth, with traces of broken shells	
	Yellow earth, gradually getting blue and of a deeper colour downward; charged with fragments of shells, increasing in quantity with the depth ...	
	Layers of perfect shells, compacted into a hard bed	about 3
	Very black soft earth, with some fragments of shells...	[? about 4]
	Dark pebbles and sand	2
	Hard green sand, with dark stripe at bottom	[? over 4]

Light-coloured clean [? Thanet] sand, not bottomed."

ORDINARY MEETING.

FRIDAY, JUNE 1ST, 1900.

W. WHITAKER, B.A., F.R.S., President, in the Chair.

Sir Henry H. Howorth, K.C.I.E., M.P., etc., Geoffrey A. Longden, and John B. Miles, B.Sc., were elected members of the Association.

An interesting address on "Our Older Sea-margins" was delivered by Sir Archibald Geikie, D.C.L., F.R.S., etc. The coast terraces of North-Western Europe, and more especially those of the east and west coasts of Scotland were described and illustrated by means of the lantern. After discussing the various theories of their origin he pointed out the importance of obtaining more accurate measurements of the heights of the terraces with the view of determining any inequalities in their levels, and he suggested this research as one in which valuable services might be rendered to geology by any competent observer who had time and enthusiasm to devote to it.

ORDINARY MEETING.

FRIDAY, JULY 6TH, 1900.

W. WHITAKER, B.A., F.R.S., President, in the Chair.

F. P. Mennell was elected a member of the Association.

The following paper was read:

"Notes on the Geology of the English Lake District," by J. E. Marr, M.A., F.R.S., F.G.S., illustrated by lantern slides.

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END OF VOLUME XVI.

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H. A. ALLEN, F.G.S.

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